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UNDERSTANDING THE IMPACT OF BUILDING INFORMATION MODELLING (BIM) ON CONSTRUCTION PROJECTS' COMMUNICATION PATTERNS

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UNDERSTANDING THE IMPACT OF BUILDING INFORMATION MODELLING (BIM) ON CONSTRUCTION PROJECTS' COMMUNICATION PATTERNS

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A thesis submitted in partial fulfilment of the requirements of the University of Northumbria at Newcastle for the degree of Doctor of Philosophy

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ABSTRACT

The aim of this research study is to understand the impacts of Building Information Modelling (BIM) on communication patterns of construction projects. This has been investigated through the identification of current communication patterns within the construction sector. A communication framework has been constructed which identifies a set of characteristics and defines benchmarks according to those patterns that can be managed during BIM implementation. This thesis has examined the issues surrounding the use of e-mail and BIM and addresses the potential that BIM has to increase electronic communication caused by traditional and disjointed working practices as well as lack of pre-defined communication protocols. This research finds that today the use of e-mail has become inevitable which promotes the exchange of documents as attachments. However, BIM is introducing new ways of working in which the industry is bound to move from a document-centric environment to a more data-driven environment utilising intelligent and data rich information models. The study continues to discuss that the integration of BIM as a collaboration platform is not as advanced as the industry sector perceives and proposes the necessity of a greater understanding of current communication practices, which can be addressed by the development of a conceptual framework of communication.

This study has utilised a mixed method strategy with a combination of qualitative and quantitative methods and it was divided into two stages. The initial stage employed two research techniques; a pilot study and focus groups. This stage was largely exploratory and set out to understand and observe current trends with regards to construction communication and used an inductive reasoning to generate a hypothesis. The second stage of the study was explanatory to explain the impacts of BIM on communication patterns of construction projects using descriptive analysis as well as using deductive reasoning to achieve a clear demonstration and a validation of the hypothesis. During this stage electronic communication patterns and peoples' activities were critically evaluated via data mining techniques on a large dataset provided by a 4Projects, a Software as a Service (SaaS) company. Conclusions of the research highlight the potential for better understanding of the impacts of BIM on communication patterns though the development of a conceptual communication framework and the use of contextualised maturity models.

This research has identified opposing views within the industry with regards to the impact of BIM on communication patterns within construction projects. These views are polarised into the belief at one extreme that BIM will lead to improved communication and at the other that BIM will lead to increased unmanaged and unreliable information exchanges during design and construction of projects. The results of this thesis also demonstrate a wide range of concerns around communication practices. These issues are due to the growth of

the industry in relation to technology, organisation size, project complexity, cultural changes and innovation. Some of the key cultural barriers include; digital engineering capability and competency, cost-driven culture, shift from document and records management to data and information management, legal and commercial aspects of project contracts, collaborative frameworks, education, training and support and leadership in a digital construction which need to be resolved in order to obtain the most benefit from BIM as a collaboration platform.

Science knows no country, because knowledge belongs to humanity, and is the torch which illuminates the world. Science is the highest personification of the nation because that nation will remain the first which carries the furthest the works of thought and intelligence.

Louis Pasteur

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ACKNOWLEDGEMENT

With growing popularity of BIM and the importance of information, there was believed to be a need for someone with a Computer Science background to take a fresh approach to BIM and construction processes. Based on this, a research proposal was put together and I was selected, as a PhD candidate, to undertake this research study. Having achieved a BSc in Computer Networks Technology, I made the decision to widen my field of knowledge and undertook a MSc in Business Information Systems Management. I then continued my studies and pursued a PhD to combine my theoretical grounding and technical knowledge with Human Computer Interaction (HCI) theories and BIM.

The admiration I have always had for Larry Page and Ray Kurzweil as well as other futurists and Social Scientists put me on the path to Computer Sciences and inspired me to apply Social and Computer Sciences in the business world. At the same time, the research methods module that I undertook during my Masters opened doors to new ways of thinking, how the world may be perceived and the roots of research philosophies including Ontology (reality) and Epistemology (Knowledge). Research paradigms then became of an interest and I started exploring the foundations of Social and Computer research. The combination of these reasons inspired me to pursue the significant challenge of a PhD research. I started in September 2010 as a full time student. Two and half years in to the PhD, I took a job with Transport for London as a BIM Consultant and moved to London to begin my journey in the Construction and the Rail industry. Since then I have been heavily involved in industry activities related to BIM.

The achievement of this research study is a lot more than what has been presented in this thesis. Although the PhD duration has been the most challenging part of my life, it has developed my personal character to be more confident, strong-willed, self-motivated, organised and objective. The choices I have made have all led me to this moment and where I am today and meet the people that have been a significant influence and support. I would therefore like to dedicate this research to my supervisors, Professor Stephen Lockley and Professor David Wainwright, who gave me the freedom to explore on my own, and at the same time provided the guidance and support needed throughout the process. I am grateful to ViewPoint (former 4Projects) for providing me with the data that was required to undertake this research and to those who participated in my pilot study. I would also like to acknowledge William Hackney and Paul Davis for numerous discussions on related topics that helped me improve my knowledge in the area. Finally, none of this would have been possible without the patience and support of my family and friends. They helped me overcome setbacks and stay focused.

I deeply appreciate everyone’s belief in me.

DECLARATION

I declare that the work contained in this thesis has not been submitted for any other award and that it is all my own work. I also confirm that this work fully acknowledges opinions, ideas and contributions from the work of others. Any ethical clearance for the research presented in this thesis has been approved. Approval has been sought and granted by the Faculty of Engineering and Environment in September 2010.

I declare that the Word Count of this Thesis is 51,618 words.

Name: Sonia Zahiroddiny

Signature:

Date:

CHAPTER 1 – INTRODUCTION

1.1 Background to the industry

Waste, in the form of time and cost in the UK's construction industry, has long been understood to be a barrier to improved levels of efficiency and effectiveness. There have been studies over the past few decades, which have identified poor information management and lack of Information Communication Technology (ICT) utilisation to be the root cause or the main contributor to the problem and have suggested how it may be resolved. Information management within construction projects is the process of the creation, use, exchange and maintenance of information.

A Royal Institution of Chartered Surveyors (RICS) discussion in 1901 found that "*drawings from architect's office are imperfectly finished and possibly incorrect*" (Blashill, 1901). In 1976 Crawshaw published a report through the Building Research Establishment (BRE) which demonstrated waste at 10-20% due to a lack of information coordination (Crawshaw, 1976). Later, in 1982, a report was published by the Building Service Research Information Association (BSRIA), which highlighted the lack of spatial coordination in Mechanical Engineering, and Plumbing (MEP) documentation which resulted in cost overruns (Michie and Ogle, 1982). All the findings from these studies highlighted the fact that "*information has been invariably inaccurate, ambiguous and incomplete*" (CPIC, 2015). Although the problem with poor information management and poor quality information has long been acknowledged, because of the culture within the industry, the situation is yet to noticeably improve.

Only in the early 90's the Government decided to take appropriate action to improve the delivery of construction projects through reducing project waste. They believed this would put them in a better position for increased competition in the global market (Cabinet Office, 2011). Through Government drivers for change, professionals within the industry were engaged to study and examine the industry's processes.

In 1991, Sir Michael Latham was appointed to carry out a review of the Construction Industry. In 1994, the Latham report, 'Constructing the Team', was published which identified a wide range of weaknesses in existing construction procedures and made fifty three recommendations to change industry practice, these reports are briefly discussed in Chapter 2.

In addition, Sir John Egan was commissioned to carry out a similar review in 1997. ‘Rethinking Construction’ was published in 1998 and continued similar themes as earlier published reports and challenged the UK construction industry for improvement through the use of Information Communication Technology (Egan, 1998). Sir Egan recommended a disciplined approach and believed in order to eliminate waste (in the form of time and cost), the process of producing and exchanging of information must change and be more integrated and more collaborative. In 2001, the National Audit Office (NAO) published, the ‘Modernising Construction’ report, which also endorsed the use of Information Technology (IT) to assist in the design of buildings (NAO, 2011). The ‘Accelerating Change’ report from Sir Egan in 2002, was another reminder to the industry of the necessity of integrated project teams using integrated IT approaches. Later on, the Construction Project Information Committee (CPIC) republished a report that was prepared in the 60’s by the Tavistock Institute, bringing together the best practices in the industry. In this report good information management was recognised as a key component which required a combination of people, process and technology.

Concepts such as Lean Construction, Collaborative Working and Building Information Modelling and how they may assist in improving the industry are established research topics. Lean and BIM principles both focus on improvements to drive efficiencies in construction processes. They are both enablers to address inconsistencies and waste within design, construction and operational processes. Although they exist as separate frameworks, they should be applied together throughout the whole asset life-cycle to realise the full benefits.

During the same time as accelerating change and the CPIC report publications, a number of public specifications for producing and managing information were issued to improve the project management capabilities as part of the BIM framework. AVANTI project(s) were selected to test these public specification methodologies. Some of the case-studies (as part of the AVANTI projects) at London Stansted Airport and the Heathrow Express demonstrated significant improvements and savings in cost (Stephens *et al*.,2005; Race and Richards, 2006; CPIC,2015). Once the best industry practice around BIM was tested and measured, a British Standard (BS1192:2007) was published with the aim to improve the quality of project information and reduce the quantity of information exchange and introducing a collaborative working culture. Never waste a good crisis was the motto and the report argued that the lack of strategic commitment at senior management and government level has also been a huge barrier to improving the industry (Wolstenholme, 2009).

In 2011 the Government released its Construction Strategy, which identified BIM as being a key enabler to facilitate collaboration between the project teams and to reduce waste. The strategy mandated BIM and stated that "*Government will require fully collaborative 3D BIM (BIM Level 2) with all project and asset information, documentation and data being electronic as a minimum by 2016 on all publicly funded projects*" (Cabinet Office, 2011). As a result, the industry has accelerated its uptake of BIM implementation and pilot projects such as Cookham-Wood, which were executed to help develop the understanding of application the BIM Level 2 protocols to real project scenarios available at the time (Glennon and Brown, 2013). The new processes required the design and handover of information to be consistently produced, used and managed following an agreed and consistent collaborative process that encourages the re-use of project data. This has been a step towards a more data-centric process which requires a centralised and fully managed information system.

1.2 Background to research study

With worldwide advances in technology and industry best practice, there is a move towards more data-driven environments. As data becomes more accessible, the quality and quantity of information grows to be fundamental to support decision making and delivering business value. However, Construction and Rail sectors are still lagging behind other sectors when it comes to leveraging information to its full potential, with information remaining a static asset.

The proposal for this research was developed based around the Government's drivers for change; moving towards a more collaborative environment in order to reduce waste. It was believed that BIM would be a key enabler to improve the quality of information produced (coordination) and reduce the quantity of information exchanges (collaboration). The driver for research outlined in this thesis was to apply Computer Science theories and its practical techniques i.e. Human-Computer Interaction (HCI), to model the complex communication networks within the industry and project teams, by recognising details of the problem and the ability to evaluate and find solutions.

In order to understand construction processes and gain a holistic view of e-mail usage and management within the industry, a number of interviews were undertaken as part of a pilot study. The interviews were conducted with experienced professionals to capture their experiences and how they view the use of e-mail within construction projects. From the analysis of these interviews, it was clear that professionals are overloaded with information coming through e-mail. Furthermore, the inappropriate integration of e-mail with electronic document management systems (EDMS), also known as project extranets, has increased issues relating to e-mail overload. Focus groups were then held to capture participant's understanding and expectations of BIM and its impact on communication. The results from the focus groups revealed that; professionals within the industry understand BIM as 3D modelling and a visualisation tool and there is lack of knowledge and understanding of its contribution as a communication or collaboration tool. At the time of these studies, questions were raised within the sector regarding the motivation behind the Government's directives to mandate BIM on all government projects. In the industry, questions were raised by the media about the contribution BIM was capable of making to the government targets and the cost of upskilling the industry compared to the potential of cost reductions.

Findings from the pilot study and the focus groups made it quite clear that e-mail is not an appropriate tool to achieve a collaborative BIM platform. It has also been observed that the goal of the construction industry is to increase productivity and efficiency through collaboration, this is realised not just by utilising a specific technical solution (i.e. enabling BIM technologies) but also by changing the way professionals work on an organisational level and the processes they perform (Butler Group, 2003). Building Information Modelling has been identified as a collaborative platform and an enabler for more efficient working in the industry (Morrell, 2011), however a conceptual framework in which to evaluate and benchmark the integration of processes must be in place before utilising BIM or any other enabling technologies.

1.3 Problem Statement

The Architectural Engineering Construction (AEC) industry has always been criticised for a lack of growth and effective delivery of construction projects (Cabinet Office, 2011). A number of academic and governmental studies have been undertaken to identify the root cause of the problems and provide pragmatic solutions to improve the efficiency and growth opportunities. There is broad consensus across all studies, with similar theme areas of problems as barriers to be addressed by the industry. All the studies have highlighted the need for a better utilisation of ICT to bring together the fragmented and dispersed project teams to improve efficiency and eliminate waste (in terms of time and cost).

At the same time, the world had become more data-driven by entering the era of Big Data, Internet of Things, Smart Cities, Semantic Web and Web 3.0. The significance of data quality and data management became ever more important to improve assurances and outcomes for decision making. Therefore, it was crucial for the Construction Industry to commit to delivering greater value through better Information Modelling and Information Management by developing its people, process and supporting technologies. For this to happen, not only existing working practices but also contractual frameworks, inconsistent procurement methods and the culture of paper and document based management needed to change to serve a more data-driven approach. As a result, Building Information Modelling (BIM) which had been around since early 90's became popular and after a number of pilot studies, led to the 2016 mandate published in 2011, and further updated in March 2016, by the Government as part of their Construction Strategy.

Building Information Modelling is a process involving the collaborative production, use and management of digital representations of the physical and functional characteristics of an asset. The resulting information models, when fully coordinated, support decision-making about a facility or asset throughout its lifecycle from earliest conceptual stages, through design and construction, operation and maintenance and eventually decommissioning and demolition. Building Information Modelling introduced a series of object-based modelling technologies for use, manipulation, simulation and analysis of data. In addition, BIM established a set of Standards, Methods and Procedures (SMP), which provide a consistent approach to the production, use and management of project information and increase the low levels of standardisation within the industry.

Technology has undoubtedly made it easier for industry professionals to create and extract data and information but there is still a lack of governance around data and information being exchanged. This is primarily due to inconsistency and low levels of standardisation within the industry, which has resulted in lack of confidence and trust in the quality of data and information being produced to support decision making. All the BIM standards and working practices that have been introduced by the Government are around data and information (dynamic) but the industry is applying the same concepts on traditional ways of working which is very document/record (static) focused. In addition, the lack of integrated project teams and systems, collaborative frameworks, consistent procurement methods and a data-driven culture have all resulted in more information duplication and overload and increase in the amount of information being exchanged, i.e. communications and transmittals.

Because of inconsistent procurement methods, disperse project environments and low levels of standardisation in relation to information structures and information model development within the industry, drawings and documentation as static records are still contractually required and accepted. As a result, BIM, which has been promoted as an object-based and collaborative platform that allows information about all aspects of an asset to be captured centrally, is being utilised as an ad-hoc electronic drafting tool with little information attached and exported as outputs.

The ease of use of these electronic drafting tools to create outputs and also because BIM allows automatic updating, information models get updated automatically every time there is a small change to reflect the changes. The updating process has resulted in additional documents and drawings to be created. At the same time, practitioners are still using the conventional ways of coordination, document management and information exchange and because of the culture of mistrust in construction all documents and drawings extracted from the information model must go through formal assurance processes to validate and verify the information. This has created not only more information for participants to exchange and distribute amongst the project team but also has overloaded them with more work of manually checking and managing the documentation.

It is essential to note that in order to achieve a collaborative environment communication protocols must be well managed and correctly aligned with business processes. There are also steps to undertake and characteristics to achieve before creating a collaborative working environment. Collaborative working refers to working practices, how contractual agreements are set and ways in which project goals are achieved. Thus, to be working collaboratively, it is not necessary to implement BIM or any other types of digital engineering technologies for that matter. Projects can well be operating collaboratively using paper drawings and paper documents as a means of communication. Technology does not replace existing methods of working but instead it is only an enabler of improving working practices and embedding efficiencies into processes. Chapter 2 expands on this and explores the areas of BIM, Communication and Collaboration to highlight the importance of communication and the impacts it would have on the success of projects which has been disregarded as a primary component of BIM.

1.4 Aims and Objectives

1.4.1 Research Aim

Although communication within traditional design and construction has been studied, with the recent uptake of BIM there is a lack and therefore an urgent need for a solid understanding of the concept and its importance within a project environment and how it can mature using enabling BIM technologies (i.e. digital engineering). Therefore, the aim of this research study is to investigate the impacts BIM would have on communication patterns of construction projects. This would establish the ground (basis) for people in the field to better understand why communication is vital and necessary to achieve collaborative working, whilst also providing a framework to build on for future work/research. The study also raises an argument that the current adoption trend of 'lonely BIM' (referred to as autonomous BIM in this study) and the use of traditional working practices will increase the amount of electronic information exchanged within construction projects, due to the lack of efficiency that more collaborative working methods would foster. This argument is based on the preliminary results from both the pilot study and the focus groups in the initial stage of the research.

1.4.2 Research Questions

The following research questions have been formulated and are answered in detail:

1. How will the implementation of discipline-based information models and the use of traditional working practices impact electronic communication patterns?
2. Is e-mail an effective means of communication for BIM enabled construction projects?
3. Are existing electronic communication systems (i.e. extranets) capable of meeting the communication needs brought about by BIM?
4. Is BIM an effective enabler for collaboration and reduced electronic communication?

All questions are answered in Chapter 7 and further summarised in Chapter 8.

1.4.3 Research Objectives

The main objectives of this study are as follow:

- To develop a conceptual map of current communication practices to visualise the existing patterns with reference to building processes
- To explore industry professionals' understandings of BIM and current methods of working in order to determine the relationship between project characteristics and level of electronic communication through analysis of real project communication data
- To understand electronic communication patterns over time through data mining and statistical analysis
- To develop a communication maturity model (4C) according to which communication patterns can be predicted and managed during implementation of BIM

1.5 Thesis Structure

With the importance of communication and rapid development of Building Information Modelling (BIM), the focus of this thesis is to highlight the impacts of BIM on communication patterns within construction projects. This thesis consists of eight chapters where all chapters are organised in sections. The current chapter (Chapter 1) includes a brief background and scope to the research area as well as the problem statement of the study. It also includes aims and objectives of the study.

Chapter two highlights the problem of communication area within Construction Industry and illustrate some research developments in the field of BIM. The importance of communication within construction projects and why there is a need to explore this topic in greater depth is explored. Furthermore, a review of other researchers' work on BIM and the efforts made with regards to BIM Maturity models are discussed.

Chapter three includes a review of the literature in the fields of Communication, Collaboration and underlying concepts and theories including Computer Mediated Communication (CMC), Computer Supported Cooperative Work (CSCW). Communication is defined in the context of this research study and the current communication mechanisms currently utilised within construction projects is highlighted.

Chapter four describes the methodology utilised in both stages of the research. The research paradigms are discussed and the chosen methodology including data collection design is detailed.

Chapter five presents the main results and findings obtained from the first stage of the research which was conducted qualitatively. The results are presented graphically using maps, tables and diagrams.

Chapter six presents the main results and findings obtained from the second stage of the research which was conducted quantitatively. The results are presented graphically using tables, diagrams and bar charts with text description.

Chapter seven illustrates the discussion put forward based on the literature review and the results obtained from both stages of the research. This chapter demonstrates the answer to research questions established in Chapter 1.

Chapter eight draws conclusions based on the literature review, results and discussion and provides recommendations for further research work.

In the next chapter, a comprehensive literature review have been conducted to establish a theoretical perspective and has been sub-divided into Communication (Wide scope) and BIM (Deep Scope) to reflect the different nature of the two main subjects under review. The development of a communication framework (communication maturity model) for BIM implementation requires a general understanding of the concept of communication, and more specifically the concept applied to the construction industry. This defines the foundation for exploring and evaluating existing problems. Furthermore, to understand the impact BIM would have on communication patterns of construction projects, an understanding of BIM theory and its practical applications/dimensions within the scope of this research is necessary. Therefore, the next chapter reviews the state of the art in the related fields of communication theories, electronic communication within construction and BIM validated by practitioners and academics to capture and understand the research and work that has been conducted so far towards a more successful implementation of BIM.

CHAPTER 2 - COMMUNICATION IN CONSTRUCTION INDUSTRY

Communication networks within construction projects have become increasingly complex and ineffective due to the temporary design and construction processes, growth of project sizes and fragmentation of project teams and project roles (Anumba*et al.*, 1997). Because of this fragmented project-based nature, participants involved may have varying levels of expertise and are usually dispersed and may rarely see each other. Not only have these conditions made an effective communication network hard to accomplish, they have resulted in inefficient exchange of information and an increase in cost and time (BSI, 2010).

Although the Architectural Engineering and Construction (AEC) industry has always been criticised for poor communication and lack of collaboration, there has been awareness of the need for a more effective communication by academic researchers, governmental reports and industry professionals (Latham, 1994; Egan, 1998; Egan, 2002; ROADCON, 2002 and 2003; Constructing Excellence, 2003; Akintoye and Main, 2007; BSi, 2010; Son and Rojas, 2011; Ballan and El-Diraby, 2011). Governmental reports by Latham and Egan published in the 1990s attempted to drive efficiency improvements in UK construction industry. Subsequent studies undertaken in 2002 by Constructing Excellence reported that across the professions within the industry there has been "*too little change, too narrowly adopted and at too slow rate*." (Egan, 1998). One potential aspect of improvement highlighted by Latham (1994) and Egan (1998) is 'communication'. Both reports identify communication as a key factor to the success of a project and suggest efficiency and effectiveness of construction processes depend on the quality of communication. They also accentuate the lack of effective communication and the need for a more integrated project delivery within construction.

2.1 Latham and Egan Reports

The Latham (1994) and Egan (1998) reports have categorised drivers of change within the industry into three main sections, which include:

- Political
- Social
- Technological

2.1.1 Political – Process and Policy

Egan (1998) trusts construction to not be any different from manufacturing. In fact, he argues that many buildings are repeat products which can be improved. More importantly, he believes project processes are repeated from project to project. Egan (1998) describes construction processes to be sequential with precise specifications and contracts defined. He continues to explain that it is assumed by professionals within the industry that clients benefit from traditional processes and from choosing a new team for every project. He is certain that continual selection of new teams restrains "*learning, innovation and development of skilled and experienced teams*".

Studies undertaken by BSRIA and BAA with support from BRE, suggest that "*there are significant inefficiencies in construction processes and there is a need for a more systematic and integrated project process in which waste in all its forms is significantly reduced and both quality and efficiency improved. This ties in with our observation that manufacturing has achieved performance improvements by integrating the process and team around the product*".

Further to this, it was first identified in 1966 that there are informal working processes within construction projects (Murray *et al*., 2000). Research undertaken by Hopper (1990) for the Construction Industry Institute (CII) in the U.S. also suggests that construction projects rely on 'informal organisational behaviour'. Informal processes are a parallel structure to formal structures and are built around the needs of "*maintaining links of communication, coordination, problem solving and decision making when the established structure isn't working properly*" (Murray *et al.*, 2000). Murray *et al*. (2000) also referred to the work of Boyd and Wild (1999) which created the "*analogy of the 'organisational iceberg' in which the amount of formal communications above the surface are underpinned and supported by a huge mass of informal communications below the line*".

In 1985 Nahapiet and Nahapiet explained that contractual agreements result in different responsibilities and relationships amongst the practitioners in a construction project. They went on to suggest that contractual arrangements provide the base lines of communication, information sharing and patterns of coordination within construction organisations (Murray *et al.*, 2000).

Latham (1994) and Egan (1998) recognise that project fragmentation and separated processes within the construction industry constrain process improvement which, reduces efficiency of project delivery. Their findings underpin the development of an integrated process. In a project with integrated processes, all participants continuously work together, eliminating waste in the delivery process and learning from experience. Egan (1998) believes that "*the industry has to rethink the process through which it delivers its projects with the aim of achieving continuous improvement in its performance and products*".

2.1.2 Social – Culture and People

As identified by Latham (1994) and Egan (1998), construction projects are fragmented and this fragmentation and separated processes promote a 'contractual and confrontational culture' (Egan, 1998). The need for cultural change to improve business processes has been highlighted by both Latham (1994) and Egan (1998). Egan believes that commitment to people is the most important asset within construction, and that respecting and appreciating people is vital in order to deliver cultural changes. Commitment to people includes:

- Educating and increasing the number of capable managers, supervisors and skilled workers
- Respect for all practitioners within a project process
- 'No-blame' culture based on trust

Egan strongly believes that if the culture of construction projects does not change, the quality will not improve and cost will not reduce.

2.1.3 Technological – Information Communication Technology

Egan (1998) considers good Information Communication Technology (ICT) to be a crucial part of improving the effectiveness of construction projects. A more effective project is the key to greater efficiency on site which will considerably improve quality. However, Egan (1998) does not recognise technology to be the only solution to the need for greater efficiency and quality in construction. He believes new technology has been utilised in the industry to emphasise and support obsolete processes where it does not work. Inspired by the manufacturing industry, he recommends a change the culture within the industry, followed by defined and improved working processes, and finally the application of technology as a tool to support the cultural and process improvements.

Technology is very functional and effective in reducing waste, improving design of buildings and in the exchange of design information throughout the construction project team. Computer Aided Design (CAD) technology, for example, is utilised to prototype buildings and exchange information on design changes. This allows redesign to take place on a computer and not on a construction site (Egan, 1998).

Information Communication Technology has already revolutionised the construction industry but there is still potential for further improvement (Egan, 1998). For example, tendering stages of projects can reduce infrastructure cost by implementing wider use of Internet technologies for e-tendering. However, comprehensive adoption of Internet technologies and 3D prototyping requires the industry to alter its conventional working practices and procurement methods. Egan's 'Accelerate Change' report (2002) identifies the key barriers to this transformation to be "*organisational and cultural inertia, scale, awareness of the potential and knowledge of the benefits, skills, perceptions of cost and risk, legal issues and standards".*

The governmental studies undertaken by Latham and Egan and the reports published by them in the 90's, originated major changes within the industry relating to Culture, Practice and Technology. Since then the industry has been undergoing significant changes with regards to working practices, technological solutions and culture.

2.2 Importance of Communication in Construction

As a species, we are social beings who live out our lives in the company of other humans. We organise ourselves into various kinds of social groupings, such as nomadic bands, villages, cities, and countries, in which we work, trade, play, reproduce, and interact in many other ways. Unlike other species, we combine socialisation with deliberate changes in social behaviour and organisation over time. Consequently, the patterns of human society differ from place to place and era to era and across cultures, making the social world a very complex and dynamic environment (Rutherford and Ahlgren, 1994, pp87).

One of the problems with modern society is that it has become so complex that no one can entirely study it any longer (Aalst and Hee, 2004). This complexity is a major social issue and construction industry is no exception. The problem within the construction industry is the complexity of projects and the various activities within the industry that necessitate engaging diverse organisations, roles and partnerships - sometimes globally - to create a communication network (Anumba*et al*., 1997; Emmitt and Gorse, 2003; Dainty, Moore and Murray, 2006). Often this creates discipline-based problems due to a group of experts and practitioners, all with different backgrounds and views working together infrequently requiring a great amount of coordination, information exchange and information management.

Murthy and Kerr (2000) and Bertram *et al*. (2010) argue that when a large number of stakeholders are involved in dispersed teams and with different expertise to work virtually, they all rely on information and therefore communication becomes an essential part of their processes. This is also true in construction; because of the isolation in the construction industry, projects are highly reliant upon updated information, therefore the exchange of information is regarded by the industry as crucial to establish effective communication protocols between participants (Thomas *et al.*, 1998; Anumba and Evbumwan, 1999; Cheng *et al*., 2001; Deng *et al*., 2001; Wikforss and Lofgren, 2007).

The amount of information created and exchanged during the life-cycle of a project is vast, which makes information management a complex and challenging task (McLeod and Hare, 2010). Therefore, important and relevant information must be acknowledged and distributed to the right members of the project team (Deng *et al*., 2011). Cross and Cross (1995) explain that the fact that different disciplines have different understandings and interpretations of design concepts and problems that significantly affects the information gathering and sharing.

Gushgari*et al*. (1997) identified communication '*as the most critical attribute to long term profitability*' by undertaking a survey of 500 engineering firms throughout the USA. They identified 'communication' and 'listening' as the most needed skills. According to Sommerville and Craig (2006) "*projects rely heavily on timely transfer of information because it forms the basis on which decisions are made by the distinct professions within the industry*". Projects can be improved through the implementation of effective communication networks and as a corollary they can fail due to poor communication. Therefore, communication is one of the major challenges to the success of a project (Thomas *et al*., 1998). In literature four main reasons have been identified as to why it is important to improve communication:

- Minimising project failure
- Innovations and better use of ICT
- Communication improvements in early phases of projects positively influence the quality as perceived by all stakeholders involved
- Better decision-making

Despite the relatively recent uptake of ICT and the Internet by the industry, many projects still rely on traditional means of communication such as face to face meetings, phone calls, fax, post or physical delivery of paper drawings. Stakeholders also use traditional methods of communication to share and manage information, and paper-based communication still remains the main channel of communication. This is due to the contractual nature of the industry. This was observed by Sommerville and Craig (2006), Howard and Bjork (2008), Ballan and El-Diraby (2011) and this research has found similar patterns to be dominant in certain sectors of the industry.

2.3 Traditional Communication Methods in Construction

The traditional means of communication in construction is to manually create project documentation and 2 Dimensional (2D) drawings which are geometric shapes with no intelligence, and communicate these documents from initial stage of design to client approval and construction. This has made construction projects heavily document-oriented (Mao, Zhu and Ahmad, 2006). Individual professions have different objectives and priorities and they use their exclusive information and documentation process to achieve goals (Sommerville and Craig, 2006). Individuals involved in a project, from the client start up to the closure of the project and facility management, organise specialised information that others will use at various times to undertake tasks. The result is a huge amount of specialised and complex information. Moreover, professionals have become heavily dependent upon information provided by other professionals to ensure their own contractual responsibilities (Sommerville and Craig, 2006; Neff *et al.*,2010; Perumal and Abu-Bakar, 2011). Therefore, it has become harder for project managers to manage communication channels, flow of data, information sharing and information processing between project participants, particularly on bigger and more complex projects (Sommerville and Craig, 2006). Information processing refers to "*the process how the information is collected, analysed and transferred*" (Peansupap and Walker, 2005).

De la Garza and Howitt (1998) observed that traditional procurement methods are 'obsolete' because they cannot "*deliver Just In Time (JIT) information at critical stages within the overall process*" (De la Garza and Howitt, 1998). This is one of the many reasons why the industry has been criticised for poor communication and has been incapable of managing and exchanging project information in a multi-disciplinary and multi-national industry (Eriksson and Laan, 2007; Latham, 1994). The need for smooth transfer of information and future use of information amongst project participants has led the industry towards a more effective use of IT and communication technologies. This is to capture and manage project information effectively as well as improving cross discipline communication (Sommerville and Craig, 2006).

2.4 Recent developments in Construction

Architectural, Engineering and Construction (AEC) industry within the UK continually completes and delivers projects with varying degrees of complexity. However, the industry as a whole has been recognised to have a defective rate of profitability, low investment in research and insufficient training that are 'too low to sustain a healthy development for the industry' (Latham, 1994; Egan, 1998). Further to this, many of the clients of this industry are unsatisfied with its overall performance compared to other industrial sectors (Egan, 1998). This situation is not limited to the construction industry within the UK; a comparative study on U.S. construction industry and other non-farm industries concludes that compared to other sectors, construction has suffered from low performance. This industry is not showing significant increase in productivity since 1964, as illustrated in Figure 1 (Eastman et al., 2011).

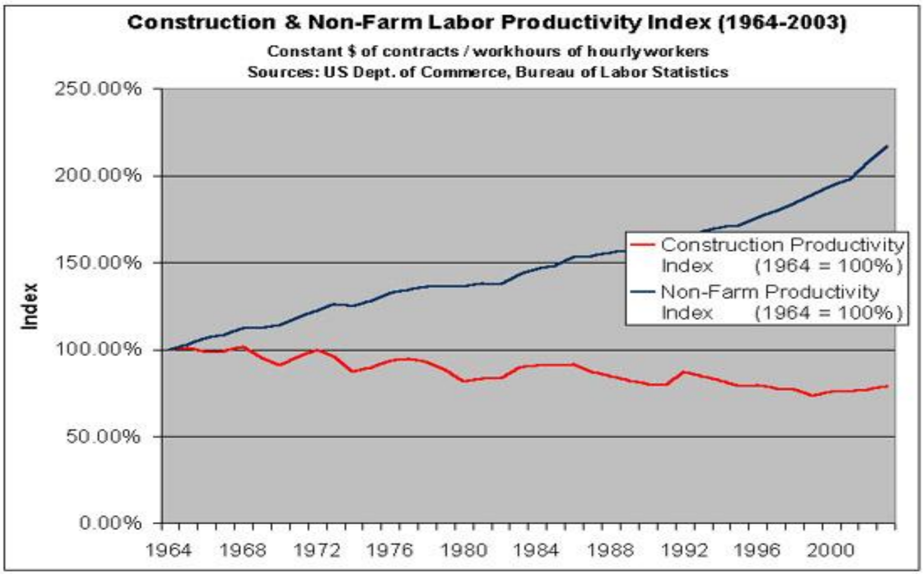


Figure 1 : Labour productivity index for the U.S. construction and non-farm industries 1964-2009 (taken from BIM handbook)

AEC is a multi-disciplinary and multi-national industry, which has an important role to play within the UK's overall domestic economy. It is a major contributor to UK Gross Domestic Product (GDP) with approximately 10% GDP (Egan, 1998). It is also a major contributor to historical UK output growth and a driver of growth in other sectors due to its heavy reliance on an extended and varied supply chain (UKCG, 2009). Because the construction industry is an important sector, maximum output is expected from it (UKCG, 2009).

The construction industry has recognised the need for substantial changes in its overall structure not only to modernise and enable the improvements in the working processes of projects but also to tackle other severe problems and maintain a healthy development. The inefficiency of the construction industry and the need for change has been mainly highlighted in governmental reports published by Latham (1994) and Egan (1998). Their ambition for a modern construction industry in the UK hinges on the "*adoption of the model of dramatic performance improvement that other industries have followed with such success, in order to deliver the challenging targets for increased efficiency and quality that we know are achievable*." (Egan, 1998). This is based on studies they performed on the manufacturing and service industries to observe and understand their drivers for radical changes and see if the construction industry can learn from their successes and seek improvement through re-engineering construction (Egan, 1998).

2.4.1 Lean thinking in Construction – Lessons Learnt from Manufacturing

Egan (1998) identified the success and the increase in efficiency and transformation of infrastructure of manufacturing companies that implemented the concept of 'lean thinking'. The term 'lean' in manufacturing also refers to the Toyota Production System (TPS) as demonstrated in Figure 2 (Liker and Lamb, 2000). Lean thinking originated from TPS and focuses on value-added processes that eliminate waste and deliver continuous improvements in efficiency and quality (Egan, 1998; Liker and Lamb, 2000).

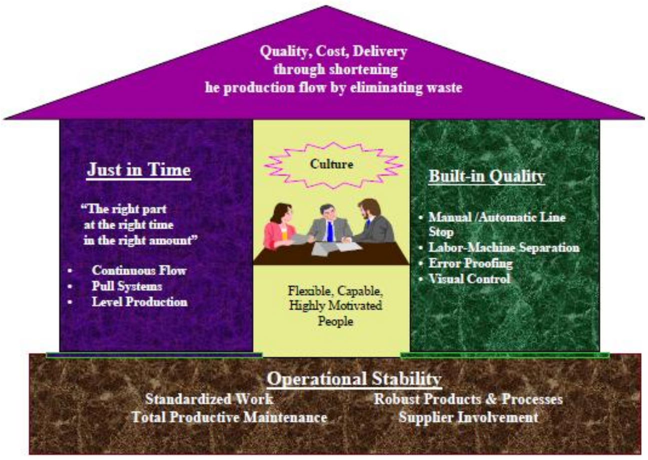


Figure 2: Toyota Production System taken from Liker and Lamb (2000)

Koskela (1992) studied the implications of lean thinking on construction projects. In his report, he suggests that clear improvements could be made in construction by identifying and eliminating non-value added activities.

Egan (1998) also investigated the philosophy of 'lean thinking' and how it may be applied in the construction industry. Koskela (1992) and Egan (1998) both found that 'lean thinking' had already been adopted with success within some construction companies in the U.S. Hence, their recommendation to the UK industry is that it applies "*lean thinking as a means of sustaining performance improvement*" through eliminating waste and non-value adding activities from processes (Egan, 1998).

Recent studies by The BIM Task Group (2013) and reports for the Government Construction Cabinet Office (2011) have also highlighted the benefits gained from implementation of lean techniques. They argue that lean thinking applied to construction will support real-time collaboration and information sharing between key stakeholders; this will reduce waste in delivery processes and allow a more controlled environment through all levels of the supply chain (BIM Task Group, 2013; Cabinet Office, 2011).

2.4.2 Lean Environments - Shift from information sharing in 2D to 3D

As discussed, traditional working practices rely upon documents and drawings. Project information is communicated through several separate and inconsistent 2D drawings and documents, which are usually outputs of CAD tools and exclude the important information necessary for problem solving and decision making. However, the introduction of third generation collaborative technologies including BIM and workflow management brings a further challenge to the conventional methods of communicating. BIM enables the production and delivery of a 3D model and a fully centralised federated dataset through which information about all aspects of the construction project can be accessed. Together these technologies create the potential for an effective communication mechanism which are spatially aware and sympathetic to the working practices of the construction industry.

Building Information Modelling revolutionises the paradigm of the construction industry from 2D based drawing information systems to 3D object based systems which would change the base for documentation within the industry (Arayici*et al*., 2009). Therefore, paper-based communication and electronic file sharing of design information in 2D documentation is not anymore capable to cope with the high levels of functionality in terms of 'speed, accuracy, usability, ease of modification, enhanced visualisation and improved coordination' required (Anumba and Evbuomwan, 1997). As a result, project teams need to transfer the exchange of information that is currently being channelled via e-mail to more appropriate tools.

The construction industry needs to enable dispersed professionals to work towards a lean environment (collaborative environment), utilising digital engineering technologies to work on a single set of structured and controlled documents (information containers in case of BIM). The concept of a single collaborative platform essentially divides into an organisational view and a technical view:

- Organisational view - the need to support the requirements of a multi-disciplinary team, from various organisations, based in different locations utilising their own ICT systems, drawn together temporarily to plan, design, construct and manage the operations of buildings.
- Technical view – the need to map and merge various independent ICT (database in case of BIM) systems into a single unified database. This would avoid information being scattered amongst several databases and would replace restricted and localised databases with a centralised repository that can be accessed by all authorised team member.

As a consequence, a single collaborative environment would enable project teams and project participants to work on a single set of structured and controlled information. This would also be beneficial in terms of integrity of working processes, effective sharing and reuse of information, faster completion of tasks and a single version of the truth. However, there is evidence that many collaborative working concepts do not reflect the ways in which individuals work in reality (Charlesworth, Davis and Holden, 2003).

For a lean and collaborative environment, it is vital that information is managed and organised into a framework i.e. a 3D information model that represents the evolving design. This will form the basis of effective information sharing amongst project teams or individuals who perceive the goals and the problems differently depending on their expertise and knowledge. Therefore, establishment of a project information model is mandatory and becomes valuable for communication (Miao and Haake, 1998). According to Ahmad, Russell and Abou-Zeid (1994) a shared data repository will "*promote integration of operations and functions within and among various design and construction organisations*". They believe the use of a shared data source would change traditional interactions and responsibilities and a new type of interdependence would emerge. As a result of this, communication channels and organisational strategies have to be re-defined and improved to move the focus towards integration and coordination.

2.5 Current Communication methods

Rapid development of ICT and web 2.0 technologies over the last two decades has produced various technological innovations to create, transfer and store information in many disciplines (Emmitt and Gorse 2003; McLean,Wainwright and Oliver, 2010). Equally, an increasing number of people are connecting to the Internet as the world moves into a new age of globalisation. (Leiner*et al*., 2009). The Internet is a versatile medium that "*challenges traditional theories and concepts of interpersonal and mass communication*" and facilitates a means of information distribution, communication, collaboration and individual interactions through e-mail, file transfer and other complex systems that supports team works devoid of location or time (Bubas, 2001; Deng *et al*., 2001; Leiner*et al*., 2009).

As new technology is adopted rapidly in the construction industry, a communication revolution has been brought about by internet technologies, e-mail, and an explosion of social networking applications. It is anticipated that the extended use of ICT will improve working practices in the industry and facilitate the development of more efficient collaborative workflows (ROADCON, 2003; Rivard*et al*., 2004).

A review of the literature indicates that the construction industry has shifted from a more traditional method of paper-based documents to electronic-based means of communication. There are electronic systems such as e-mail, extranet sites and FTP links to transfer information and provide immediate access and up to date documents; nevertheless hard copy documentation remains as the permanent record of information (Sommerville and Craig, 2006). Professionals within the industry still utilise CAD tools for design purposes and later print these designs in hard copies to communicate to the rest of the project team (Neff *et al.,* 2010). This method of communication is essentially hard to retain, time consuming and results in information being duplicated or lost. Consequently, the construction industry has been undergoing significant changes to improve its traditional communication practices and to become more information focused and better at information exchange and management (Sommerville and Craig, 2006).

2.5.1 Channels of Communication

Means of communicating in construction projects have been divided into two sections by Hunter (1993) and this has also been highlighted by Xie (2003):

1. Traditional – which is the "*transmission of verbal and non-verbal messages. The end product of the nonverbal communication is always recorded on paper via pen, typewriter or printer*."

2. Electronic – which is the "*transmission of verbal and non-verbal messages from one electronic device to another in such a manner that the message remains and is heard, read or viewed in the electronic form.*"

Ballan and El-Diraby (2011) and Wikfross and Lofgren (2007) have also found that day to day activities and personal interactions have been communicated at both formal and informal levels. Formal communication refers to controlled exchange of documents and informal communication which is about common problem solving (Wikfross and Lofgren, 2007).

2.5.1.1 Email

Documents are increasingly transferred via e-mail (unstructured text), often as attachments, but storage, archival and management of documents is undertaken by the receiver. A document is an 'information carrier' which contains written or drawn information and can be created, transferred, stored and managed as a unit (Löwnertz, 1998; BS1, 2007). In construction, documents are immutable and are created and stored as single computer files, manifested in one or more information containers: file, printed report or e-mail (PAS1192-2, 2013).

However, due to the limitations of e-mail systems, information from the sender must be abbreviated and summarized to a level that facilitates the transmission. Therefore, some information must be reconstructed from the e-mail message; the greater the level of summarisation, the greater the potential for error during reconstruction. This will result in time and effort being wasted, which according to Daft and Lengel's Media Richness Theory, would be low in richness. Media Richness Theory (MRT) was initially proposed by Daft and Lengel in 1986 and provides a conceptual framework to demonstrate that different communication mediums vary in capability by which they can convey information and rank the richness of a communication medium (Ngwenyama and Lee, 1997).

Although, some studies in the 90's identified theoretical and practical limitations in MRT and argued that e-mail can be considered to be a rich media (Ngwenyama and Lee, 1997; Kinney and Watson, 1998), other studies such as Suh (1998) and previous research studies concluded that 'computer-mediated text mediums' such as e-mail are too low in richness, demand the most time for decision making and therefore are ineffective because of their incapability to transfer information adequately. Even though e-mail as a communication medium is low in richness and can only communicate a certain amount of information, people do still prefer to use it (El-shinnawy and Markus, 1997; Ballan and El-Diraby, 2011).

Results of a survey undertaken by Dainty *et al.* (2001) demonstrates that one of the main obstacles to improve performance in construction is the 'poor quality of information'. Therefore, although the amount of available documents (information) has increased, the majority of the information shared by project participants does not add any value to the overall project (Phelps, 2012).

One of the reasons for incorrect perception and usage of e-mail in construction is the lack of research undertaken in this field. Existing literature suggests that there has been little research in the usage of Electronic Communication and E-mail within construction project teams and the focus has been mainly on e-mail as a tool that reduces the time to transfer information and design and development of new internet-based applications to share and exchange information (Deng *et al*., 2000).

2.5.1.2 Extranet

Today, a new type of Internet-based products are available that will enable project teams to establish e-environments (McLeod and Hare, 2010). These e-environments, so called 'extranets' can be utilised, by project teams, to share and exchange a variety of project information with all their stakeholders (both internal and external). Extranets or Electronic Document Management Systems (EDMS) are applicable for managing large amounts of documents and drawings (i.e. records) created during a project's life-cycle together with the related metadata (Lownertz, 1998; Ruikar, Anumba and Carrillo, 2005). "*Metadata is structured information that describes, explains, locates, or otherwise makes it easier to retrieve, use, or manage an information resource*" (NISO, 2004). In a digital world, metadata promotes interoperability and supports archiving which enables a more seamless search across the platform (Foulonneau& Riley, 2008). According to Bjork (2003) it is essential to differentiate between the main information within a document (i.e. content) and the information about a document (i.e. metadata) for document management. Metadata allows users to search for and retrieve a document from a database.

In a project–based and task-oriented environment the exchange of documents and feedback messages is crucial (Derks and Bakker, 2010). However, a substantial problem with construction projects is essentially their poor and unreliable document management during the project life-cycle, especially considering that the use of Document Management Systems (DMS) can be called upon to provide structured document based evidence that can be used to settle disputes. The exchange of information is a key function to the success of any construction projects and the success of this function is dependent on the efficiency and effectiveness of the DMS.

Today, paper has largely been replaced by computer files stored on servers or some other digital medium. Nevertheless, "*there is not a one-to-one relationship between a document and a file*" (Lownertz, 1998). A file may contain several documents, a document also may collect parts of several files. Lownertz (1998) has clearly distinguished that in practice, the basic task for document management is the clarity/definition of document properties and relationships. Therefore, a complete computer-based system for the purpose of document management has to have the capability of dealing with the stored elements as well as the documents. Lownertz (1998) continues his discussion by saying an environment, such as a construction project, with paper-based and digital documents do exist, which means a document management system should function independently of the stored elements. Information has different forms and each form is regarded as a unit that should be managed in the information exchange process.

Sommerville and Craig (2006) identify Document Management System (DMS) as a tool used to simplify and re-structure 'communication'. They also perceive an integrated DMS to encourage integration and improve the collaborative, integrated culture that was urged in Egan and Latham's report. But they continue to argue that "*DMS have often been viewed as a non-value added component of the construction process*". For that reason, many construction projects endure the "*consequences of poor information and administration procedures*."

Based on an observation by Mead (1999) project intranet systems (internal EDMS), if used appropriately, act as a major role in project 'communication network' and project 'communication effectiveness'. He believes "*intranets also have a positive effect on the timeliness and understanding of project information and their use can improve the speed with which information is transferred between project players*". However, he continues to add that intranet use appears to overload project professionals with information.

The use of Internet and internet-based technologies has been very effective within construction projects, since the Internet has developed a communication platform for a more effective information transfer. With the use of Internet not only is information transfer faster, it is also traceable. Besides, it is cost efficient compared to traditional means of communication and creates savings in communicating with distant stakeholders through computer networks (Deng *et al.*, 2001).

As ICT has evolved and its presence has expanded, companies invest in ICT more than before and this has changed the speed and shapes of businesses (Sward, 2006; Carr, 2003). Since the general assumption is that ICT increases productivity, the researchers have focused on finding evidence for this correlation. According to (Sward, 2006), researchers have demonstrated the connection between ICT and productivity by comparing business-value outputs with inputs and have substantiated a positive return on ICT investments. Therefore, consensus amongst business professionals was developing on the role of IT in improving productivity (Sward, 2006).

However, Carr (2003) has identified ICT to be a 'transport mechanism' which carries digital information and argues that ICT has become a commodity and investment in ICT alone will not improve productivity. Sward (2006) in accordance with Carr's claim continues to explain that companies need to manage their business processes as well as investing in ICT. Sward (2006) also found that companies need to manage their business processes, and those companies that invested in ICT without making the required organisational changes did worse than companies that did not make an investment.

2.5.2 Lack of automated integration

Electronic Document Management Systems have been beneficial to the industry by providing consistency in document generation, exchange of documents, ease of access, ease of use and managing projects. In fact, EDMS have improved the quality of documentation and have produced more structured information (Sommerville and Craig, 2006). However, its true potential has not been fully realised since construction projects still use e-mail as a means of exchanging information and both e-mail and EDMS work as unincorporated and stand-alone systems.

Wright (1998) defined an integrated project information system to be a central, dynamic repository for project-specific information which would be accessible to all project participants at all times, such as an EDMS. With the increased use of ICT some measure of integration was achieved, but lack of strategic approach to adoption of computer tools, inadequate communication protocols and persistent use of discrete digital engineering tools has resulted in 'islands of automation' (Anumba and Evbuomwan, 1997)**.**

A review of the literature indicates that communication, in particular electronic communication in the design process is undergoing significant changes (Anumba*et al.*, 1997; Brown, 2001; Fischer*et al.*, 2002; Jernigan, 2008). However, Lownertz (1998) and Jernigan (2008) believe managing documentation has not undergone a corresponding change and managers are still using "*non-integrated*" communication tools. According to Sommerville and Craig (2006) "*construction projects have significant embedded information and generate considerable quantities of real time information prior to and during execution*". With regards to sharing project information and management of projects, documentation needs to be structured; therefore, there is an increasing demand for ‘integrated information systems’ to allow project participants to share project information. Sommerville and Craig (2006) believe that unreliable and inaccurate information could have an effect on the ‘ability to make the correct decision’.

Because of the complex nature of the industry, multiple phases of a project life-cycle, dispersed and multi-disciplinary project participants and the use of various information system tools, systems integration has become a vital requirement to achieve an effective communication and success in construction projects (Shen*et al.*, 2010; Phelps, 2012). A properly structured and integrated approach for the delivery of information to the right person at the right time and in the right format is seen as a means for overcoming the typically ‘ad hoc’ (almost sporadic) nature of project communication.

Construction projects have recently begun to recognise the importance of electronic sharing of information during the life-cycle of projects. There is lack of automated integration within construction projects and project information is still being managed by project managers and Document controllers, using Workflow Management Technologies (WMT) to route and automate tasks (ROADCON, 2003; Sommerville and Craig, 2006). Automation is defined by an “*activity which is capable of computer automation using a workflow management system to manage the activity during execution of the business process of which it forms a part*”. (Workflow Management Coalition, 1999). The ability to automate the exchange of process information between computer applications is important for computer-based collaboration in construction.

The lack of automated integration in construction project teams and construction communication has been highlighted mainly by ROADCON report (2003) and Ballan and El-Diraby (2011). But as technology grows rapidly in construction industry, it is anticipated that a better use will be made of it, to promote integration, improve the working practices and develop more efficient collaborative workflows (Ahmad, Russel and Abou-Zeid, 1995; ROADCON, 2003). Widespread use of CAD and electronic documents has increased the levels of integration and automation demanded between office tools, e-mail and project collaboration tools. This is the backdrop to the industry’s attempts to accommodate 3D data models by treating them as electronic documents. The construction industry needs solutions to enhance automation and integration of available communication technologies to improve traditional business processes (ROADCON, 2003).

In order to automate the transfer and sharing of information between project participants, some of the communication restrictions that currently exist in the industry need to be reviewed and perhaps broken. Regular exchange of information in a disciplined manner will also change the culture of industry and will create a freely exchanged information environment based upon mutual trust (Sommerville and Craig, 2006).

2.6 Building Information Modelling

Today construction is undergoing big changes due to the introduction of Building Information Modelling (BIM), which brings potential conflict to the established traditional ways of working (Eastman *et al.*, 2008). BIM is a new technology and a set of processes for handling structured data, which enables the visualisation and development of intelligent objects and 3D spatial models of buildings and infrastructure assets. BIM should be implemented as a single database consisting of 'fully integrated and interoperable information' that can be used seamlessly and concurrently by all project professionals throughout a project's life-cycle (Stanford University, 2008). It provides an integration of disparate processes and technologies to allow organisations to better connect and work on construction projects. It is an information resource with embedded metadata with number, name and meaning of each element characteristics. According to ASHARE report (Stanford University, 2008) true BIM is a "*model where three dimensional (3D) graphical imaging carries real-time (i.e. immediate and dynamic access) data, and where every line and every object carries real-life intelligent physical and performance data*".

In computer science, researchers have adopted the phrase 'a picture is worth a 1000 words'. Since the term BIM covers a wide range of concepts, there is no common definition for the entire industry. Organisations and individuals, based on their expertise and positioning within the project and asset life-cycle, have come up with their own definitions. For the purpose of this research study, BIM is defined as: the consistent collaborative process for the production, management and delivery of digital representations of the physical and functional characteristics of assets over their life-cycle. Technologies underpinning BIM enable the development of 3D spatial models to support data analysis, visualisation and reporting. BIM is a major information repository with embedded intelligent objects and metadata with number, name and meaning of each element characteristics. With the emergent use of BIM, the communications and their content will refer to spatial entities and specification. A BIM environment would reduce the resistance to data exploitation and interaction by reducing the effort required to access and display increasingly large amounts of information.

Succar (2009) refers to BIM as "*Vital for Communication*". "*The adoption rate for BIM in the United Kingdom among construction professionals surveyed is 35%*" (MacGraw-Hill, 2009). BIM is adopting the right set of processes as well as finding the right tools to construct a shared information resource which represents a 3D model of a building merged in with a full database of the project, forming a consistent source for decision making in a project life-cycle (MacGraw-Hill, 2009; buildingSMART, 2010). Underwood and Isikdag 2010 believe BIM is a significant technology for supporting interoperability, capturing knowledge and communication throughout the project lifecycle.

The importance of communicating BIM information has been highlighted in many recent published governmental reports. BS1192 (2007) states that collaboration between project participants is essential to the efficient delivery of projects. It demonstrates that more organisations are working collaboratively in order to accomplish "*higher standards of quality and greater re-use of existing knowledge and experience*". It continues to explain that communication and sharing information effectively are key elements of these collaborative environments. Also in comparison to U.S. non-farm reports; Teicholz 2004 report on increased drop in construction labour productivity, the UK Cabinet Office (2011) and The BIM Task Group (2013) have published a number of reports to demonstrate that BIM can improve communication, productivity and have already illustrated major savings derived from implementing BIM. However, they argue that BIM is only one part of the overall strategy and if exploited in a join-up approach with other related techniques such as 'lean' practice, will lead to even more vivid improvements in the construction performance.

The construction industry has yet to appreciate the fundamental benefits of third generation collaborative technologies (DiVanna, 2003). These technologies will affect the organisational structures and alter the roles and responsibilities of employees. BIM enables the use of "*three dimensional, real-time, intelligent and dynamic modelling*" which can be very beneficial in facilitating collaboration (Stanford University, 2008). This will allow all participants to share, apply and update project information in real time and simultaneously.

Technologies that underpin BIM have their roots in Group Support Systems (GSS), which allows participants within a project to interact and share structured information instantly to solve problems and make decisions. Decision making and problem solving tasks entail project individuals to discuss alternative points which require more communication and sharing of information. It has been discussed GSS groups may not out-perform face-to-face groups because of the increased need for 'richness' in the communication media for such tasks. However, BIM is believed to be an 'information rich repository', which consists of several containers of information related to a building model.

2.6.1 Advantages of BIM

Building Information Modelling has been identified as an important area in Construction both within current research and the industry and is expected to improve project delivery through (Ballesty, 2007; Arayici, 2009; Eastman *et al*., 2008; BSI, 2010):

- Improved Communication and Collaboration
- Consistent approach to data procurement
- Data-driven approach to the production, management and delivery of information models
- Assurances and validation of the quality, integrity and completeness of information
- Achieve target cost by eliminating waste (in the form of time and cost)
- Open and reusable structured information
- Undemanding information sharing
- Intelligent and flexible documentation
- Scattered access and retrieval of information
- Improved information governance and information security
- Less RFI's and Change Orders
- Clarity in construction sequencing and improved energy analysis and simulations
- Improved stakeholder engagement through better visualisation and simulation of design
- Multidisciplinary coordination
- Improved Asset and Facility Management
- More efficient working processes through process integration and having a common data environment

Albeit, no study has explicitly demonstrated a robust methodology for realising the benefits that can be achieved from the utilisation of BIM.

2.6.2 Disadvantages of BIM

Some of the barriers and challenges in implementing BIM that have been highlighted by researchers are listed below (Lownertz, 1998; Arayici, 2010; Gu and London, 2010):

- Lack of knowledge
- Lack of training and upskilling
- Dispersed nature of the AEC
- Resistance to change the existing work practices
- Reluctance to adopt new technologies
- Lack of clarity on roles and responsibilities

- Adjusting existing working practices to lean-oriented processes
- Lack of highly developed technology (hardware and networking resources)
- Lack of integration and interoperability
- Hardware and Software costs and the overall cost of BIM adoption
- Ownership of the model/ liability and insurance issues
- Generation of 2D documents for permits

More and more studies are emerging to address these limitations and provide guidance on how the ‘soft’ aspect of BIM need to be tackled.

2.7 Review of BIM Studies

Jung and Gibson (1999) studied Computer Integrated Construction (CIC) implementation in an attempt to develop an Information System (IS) planning methodology prioritising construction business value chains for a more effective management. On the other hand, with the increase growth of BIM, Jung and Joo (2011) expanded the CIC concept, in terms of optimising the use of IS in the construction industry, in order to maximise the benefits. They proposed a BIM framework providing a basis for identifying and evaluating driving factors for practical BIM effectiveness.

Wix and Katranuschkov (2002) studied and analysed construction processes based on the Generic Process Protocol (GPP) coupled with the UML techniques. Using GPP, they captured different roles, activities and communication together with their interrelationships on a high-level, then utilising UML diagramming they drew a detailed representation of sub-processes.

Nour (2006) addressed the problem of workflow management in collaborative environments as part of an integrated project co-funded by the European Commission within the Sixth Framework Program. Nour’s approach to workflow management was by splitting and merging IFC sub-models (partial models). There have also been other studies exploring and presenting industry experiences using IFC data modelling format for exchanging BIM models between various software tools.

Suermann and Issa (2009) measured the perception of the impact of BIM with regards to six primary construction key performance indicators (KPIs) through undertaking four surveys. The six KPIs, in order of the highest rated to the lowest rated were: Quality Control/Rework (90%), On-time Completion (90%), Cost-Overall (84%), Units/Man hour (76%), Dollars/Unit (70%), and Safety (46%). The result of their study indicated that a BIM approach would improve construction metrics in comparison to conventional methods of working practices.

Succar (2009) introduced a BIM framework and a set of interacting policies, processes and technologies which identifies a series of stages that stakeholders need to be aware of and implement gradually. The BIM domain is comprised of three interlocking yet distinctive 'fields of activity' (Figure 3): Technology, Process and Policy. Each one of these BIM fields has its own players, requirements and deliverables. Interactions between these fields are "*push-pull knowledge transactions occurring within or between fields*" (Succar, 2009).

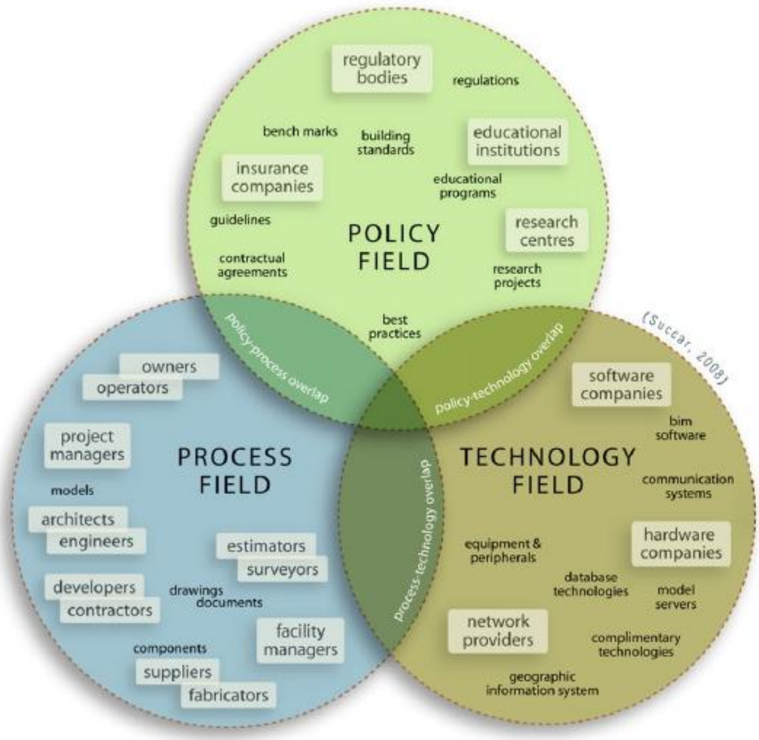


Figure 3: Three interlocking fields of BIM activity taken from Succar (2009)

The Policy Field is a group of players who prepare project participants for tasks including 'delivering research and allocating risks'. The Technology Field is a group of players who concentrate on expanding 'software, hardware and networking systems' to improve productivity of projects. The Process Field is a group of players who 'design, manage and maintain' project structures (Succar, 2009).

Gu and London (2010) studied the current state of BIM in Australian construction projects and analysed the readiness of the industry to position BIM adoption in terms of current adoption and expectations across disciplines. They found that there are varying levels of BIM adoption. Gu and London (2010) continue to explain that even the early technology adopters have varying levels of practical and empirical knowledge of BIM and therefore there are different understandings regarding the future implementation of BIM. They also suggested that there are various factors affecting BIM adoption which can be grouped into two main areas: technical (technological) and non-technical (human centred) issues. They firmly believe that the need for guidance on change within the industry is apparent and the challenge for the research community in BIM should not only lie in addressing technical issues or human centric problems, but also in creating a decision framework which integrates challenges within both areas. Hence, they initiated a Collaborative BIM Decision Framework to help the BIM adoption within construction industry based upon the industry's concerns.

Building Information Modelling (BIM) was introduced to address insufficient systems integration and inefficient information exchange and to move towards an integrated collaborative workflow (Isikdag and Underwood, 2010). There have been many studies in the field that have highlighted the fact that BIM tools will facilitate integration and the use of BIM in construction projects will help create a collaborative working process. But recent studies related to collaboration and automation in construction has mainly focused on connectivity, coordination and collaboration aspects of BIM. For instance, Solibri and Tekla have introduced a BIM Collaboration Format (BCF) which is XML based and introduces a set of IFC standards to facilitate workflow communication between different BIM models. The BCF is a series of files that store communication and links of the objects to these communications but does not embed the collaboration in the BIM model. The idea is to separate the 'communication' from the actual model and information related to specific building components in a model can be viewed in a different BIM tool from the same viewpoint, however it is only a snapshot of the model at that particular time.

Neff *et al*. (2010) have a comprehensive description of BIM. They portray BIM as:

- A 3D visualisation tool for mirroring/ illustrating assets
- A centralised database for building objects and components that can be queried and analysed
- A collaborative communication tool for joining different teams of experts
- A tool for translating discipline-specific software files
- A collection of datasets about a building from distinct professions

They argue that BIM is perceived to be a facilitator of communication and information exchange and it is expected that BIM will increase work effectiveness amongst designers, engineers and builders. However, their observation on industry practice demonstrates that even though BIM is 'technologically' joining project professionals more tightly together, they remain separated on organisational level. This has resulted in lack of access to important information that BIM in theory can offer. They continue to conclude that technological aspects of BIM has led to increased adoption of BIM which has allowed various professions within the industry to generate information and analyse buildings within their own disciplinary boundaries but the working practices that supports collaboration has been slow to arise.

Arayici, *et al.* (2011) undertook a Knowledge Transfer Partnership (KTP) research to demonstrate efficiency gains achieved towards a lean design practice through the BIM implementation by systematically evaluating relevant BIM technologies. Simultaneously Singh, Gu and Wang (2011) investigated and developed a conceptual framework to capture and categorise the technical requirements for using a BIM server as a multi-disciplinary collaboration. They concluded that "*greater emphasis should be placed on supporting technical requirements to facilitate technology management and implementation across disciplines*". And Forest *et al*. (2011) provided evidence that BIM supports project management learning activities and integration of project management tools.

BIM as a digital infrastructure for project delivery has been expressed as a technology with regards to organised agreed working processes and standards required for sharing information and because computer mediated exchange of information is regarded as more reliable than 'human-only' communication (Dossick and Neff, 2011). Contemplating BIM as a technology is argued by Whyte and Lobo (2010) to help project participants to improve and ultimately re-establish their working practices.

Shen and Chua (2011) discussed the benefits of three emerging Internet-based technologies: semantic search, cloud computing and mobile computing in promoting BIM adoption and introduced an integrated project management framework on BIM and above technologies to lower the entry barrier of BIM implementation. Their findings concluded that mobile computing improves the IT infrastructure and can be a fundamental component in the BIM implementation for an efficient channel for information sharing and easy access to the information models anytime anywhere. Grilo and Jardim-Goncalves (2011) undertook a similar study to investigate the feasibility of BIM combined with Service Oriented Architecture (SOA) and Cloud Computing in the context of e-procurement in construction industry and proposed a SOA4BIM framework.

Sebastian (2011) focused on legal aspects of BIM on four different project delivery methods in the Netherlands construction project teams. He believes BIM is 'only' viewed as a technology in many Netherlands construction projects. He continues to argue that such view point can sabotage 'the effectiveness of BIM to support an effective collaboration'. Thus, deciding on an appropriate project delivery method is vital to enable an integrated collaboration.

Brewer and Gajendran (2012) conducted a case study of a sub-contractor within a design and construction project; the aim of this case study was to develop an applicable investigative method to discover the link between individual attitudes and project team's culture and how they may affect the ICT and BIM implemented across temporary project teams. They discussed that a collaborative use of ICT and BIM within and between project teams can mean that project delivery within construction can be improved through "*greater coordination, reduced conflict, efficiency savings and valuable information stream*" throughout a project life-cycle. However, they believe the success of ICT, in particular, BIM within project teams relies upon participant organisations to "*share compatible technologies, business processes and culture led by people who hold attitudes and display behaviours conductive to collaboration*".

Barlish and Sullivan (2012) developed a more holistic framework for evaluating and analysing the benefits of BIM and its impact on projects' success. They concluded that a high potential for BIM benefits has been observed in the tool installation department of semiconductor manufacturing, however actual returns and investments vary on each project. At the same time Hegazy and Abdel-Monem (2012) undertook a study on proposing a low-cost framework that utilises e-mail (as an established communication media) to develop a system for progress tracking and communication within project groups.

2.8 Review of BIM Standards

Building Information Modelling maturity levels, as demonstrated in Figure 4, have been defined by a number of standards. BIM Level 1 establishes the foundations to all levels of BIM Maturity. It requires all information to be produced and exchanged digitally and emphasises the need for an information management process to be defined and agreed upfront on every project based around BS1192:2007. This standard applies to all project information and is applicable to all parties involved in the production, use and management of the information throughout the project stages of an assets life-cycle. It provides common methodologies for structured naming conventions and defines a disciplined process for sharing and exchanging information, ensuring effective information management, and sets out roles and responsibilities.

To achieve a Level 1 maturity requires the collaborative production of project information to align to a BS1192:2007 way of working. The production, use and management of Graphical data, Non-graphical data and Documentation components of the Information Model are carried out following an agreed set of Standard Methods and Procedures (SMP), utilising a Common Data Environment (CDE) with defined Roles & Responsibilities. The Information Model components are stored in a managed environment with robust governance in place aligned to both BS1192:2007 and business requirements. A fully coordinated Information Model, including discipline specific information models is expected at maturity level 1, which are typically linear, solid or surfaces in 2D or 3D, with associated data produced manually and not integrated with the models. Documents would still exist, but would be generated directly from data.

Building Information Modelling maturity level 2 is the Government's target for all centrally procured projects from April 2016. Level 2 builds on the foundations of BIM maturity level 1 and therefore can only be achieved once the level 1 requirements are firmly in place. At BIM maturity level 2 there is greater emphasis on consistently capturing and articulating information requirements to support the lifecycle management of assets and there are greater legal and commercial influences in relation to the production, use and management of data and information. BIM level 2 comprises of;

- A consistent approach to data management,
- Clear and concise contractual requirements for data procurement,
- Data-driven approach to the production of information that can be effectively shared and reused,
- Exchange and management of coordinated digital data from multiple sources through a CDE.

The Government has articulated the requirements of level 2 BIM through the following eight components and standards:

<u>PAS1192-2:2013</u>

The purpose of PAS1192:2 is to support the capital delivery phase of assets. It enables projects to specify information requirements early in the process, set out a collaborative framework and provide specific guidance on information management processes to support project teams to better understand the future use of the information throughout the project and asset life-cycle. The requirements within PAS1192-2 build on the existing code of practice; BS1192:2007. The main focus of PAS1192:2 is project delivery, where the majority of Graphical data, Non-graphical data and Documentation (known as the Project

Information Model (PIM)) are accumulated from design and construction activities. It starts with the assessment (for existing assets) or statement of need (for new assets) and works through a number of information delivery stage requirements to the post construction requirement of the delivery of an as built PIM.

PAS1192-3:2014

The purpose of PAS1192:3 is to act as a partner to PAS1192:2 to support the operational phase of assets. The PAS is for specifying a management process for the production, use and management of an Asset Information Model (AIM) from the Project Information Model (PIM), through the life of the asset up to final decommissioning. The PAS is applicable to both building and infrastructure assets and is applied to existing or acquired assets as well as those commissioned through capital works. It specifies the requirements for an organisational asset management plan which would feed into information management process during the operation and maintenance of an asset life-cycle. The PAS also provides guidance on the production, use and management of an Asset Information Model (AIM) to support the Asset Information Requirements (AIR) and Organisational Information Requirements (OIR).

BS1192-4:2014

The purpose of BS1192:4 - Construction Operations Building information exchange (COBie) is to provide a formal schema and a common structure for exchanging information about new and existing assets, starting at the start of a project and continuing through-out the project life-cycle. COBie is an international standard and defines a methodology for transmitting information for both buildings and infrastructure assets using a spreadsheet. The aim of COBie is to change the format of existing deliverables from proprietary formats to an open and international format.

PAS1192-5

The purpose of PAS1192-5 is to address cyber security issues inherent in BIM level 2. This PAS highlights cyber security implications with BIM and explains how to apply appropriate security measures (i.e. security policies) to attain and protect the organisation and its supply chain’s asset information against security risks in cyberspace. The key elements of security management include; confidentiality, integrity and availability of data. In addition, the PAS embraces security-related legal issues including protecting intellectual property, resolving disputes and roles and responsibilities.

CIC BIM Protocol

The purpose of the BIM Protocol is to create a standardised code of practice for use on all construction contracts. The protocol creates obligations for the employer and the contracted party around the production, use and management of data to provide a Project Information Model (PIM). The BIM Protocol is a supplementary legal agreement, incorporated into existing NEC3 suite of contracts with minimal amendments to contract structure. The protocol takes precedence over all other contractual documents, where there is conflict or inconsistency. It enforces suppliers to produce Project Information Models and puts into place specific obligations, liabilities and associated limitations on the use of the models. The protocol puts in place protections, for the information originators, through the inclusion of specific licences.

Government Soft Landings

The purpose of the Government Soft Landings (GSL) is to optimise the operating performance within the operational budgets as soon as possible and align the operating performance with the required performance outcomes set at the start of the design and construction period. Government Soft Landings provides a process of aligning the interests of those who design and construct an asset with the interests of those who use and manage it, the main focus being on outcomes and meeting the needs of the end users. GSL reinforces the value of Post Occupancy Evaluation (POE) in assessing the quality and performance of the finished product. The key with GSL is early client involvement to set clear targets, the cost of running the asset and the business benefit gained from it right at the start. The key areas of GSL are as below:

1. Functionality & Effectiveness – Assets should meet the needs of the occupier/ operator/maintainer and should be designed in a way that provides effective and productive environment for users. Significant factors influencing this area are: comfort, facilities and amenity.
2. Environmental Management – Assessing performance for energy consumption, carbon dioxide emissions, water usage and waste production against corporate targets, operating budgets and project targets which should be aligned to government performance targets. These elements need to be constantly reviewed and evaluated as projects progress.
3. Capital Cost and Operating Cost – Operational budget (with specified cost structure) to be provided as a key output from the Facility Management process and will be reviewed and benchmarked throughout the project process.

4. Facilities Management – A clear cost efficient strategy for managing operations of assets, then translated into operational needs, service level agreements and cost for maintenance.
5. Commissioning, Training & Handover (CTH) – CTH should be considered and planned right at the start of the project. Facility Management team need to ensure they are equipped with the right tools and have the right knowledge from designers and contractors throughout the process
6. Planning for aftercare **-** Aftercare is to support the asset to meet its optimum performance and support the end operators in providing an environment that supports the required performance. Aftercare starts when the project passes from its final construction phase and into full time occupancy. The strategy and guiding principles for aftercare need to be established early in the project and should evolve as a key part of detailed design.

Digital Plan of Works

The purpose of Digital Plan of Work is to provide a standardised and free-to-use digital tool for capturing, validating and storing information required at key project stages of an assets life-cycle. Digital Plan of Work is applicable to all new build projects and major refurbishments. It is a generic schedule of phases, roles, responsibilities, assets and attributes made available in a computable format. Digital Plan of Work will allow for the gathering of data for specific uses (e.g. answering plain language questions for the client and project team) and in turn provide greater certainty and clarity for the delivery of information against initial requirements.

Classification

The purpose of Classification is to provide a standardised structure of data and information to be categorised and indexed to make it easy to understand and more accessible in a common format throughout the project life-cycle and beyond. Classification systems are essential tools for organising project data or information systematically and consistently. They will map project information and will ensure interoperability between different information systems and asset management tools with data entered once and re-used thereafter.

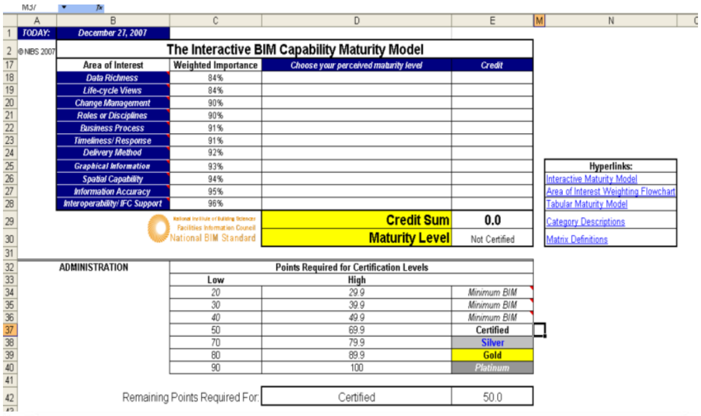
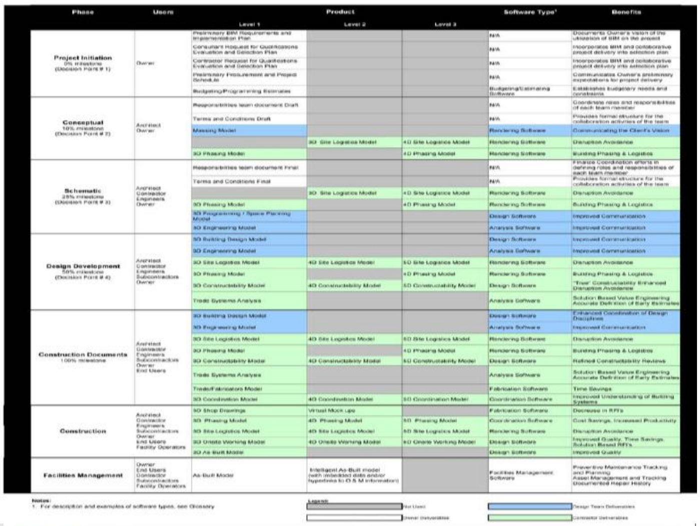
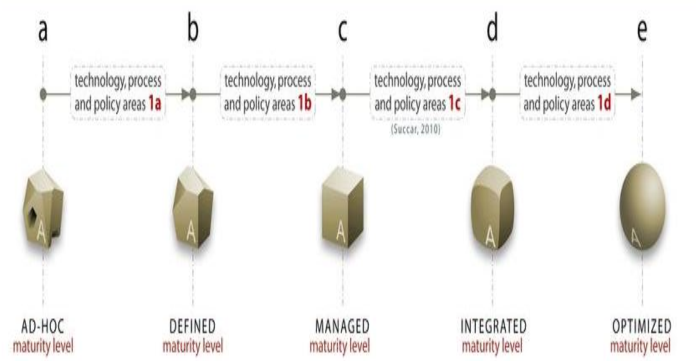
2.9 BIM alignment with Maturity Models

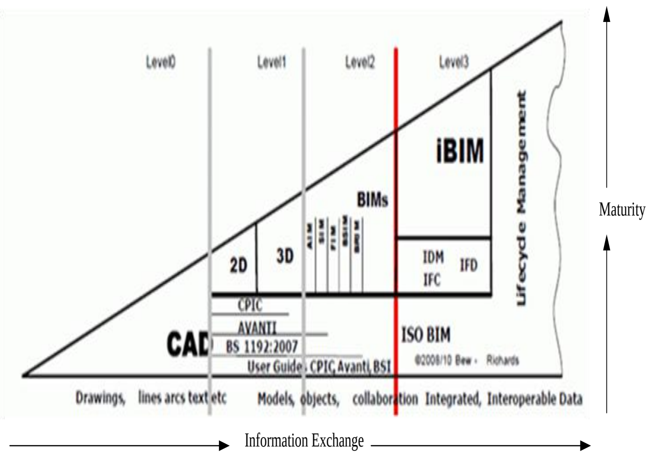
Even though the emergence of BIM has become very popular, there is still a lack of reliable benchmark with regards to BIM Maturity (BIMM) within construction projects (NIBS, 2007; Chen, Dib and Cox, 2014). A Maturity Model is defined as a process improvement framework and consists of Maturity Levels which indicate the process, technology and policy improvements within each BIM stages (Succar, 2009). A Maturity Level according to Succar (2009) is a pre-defined 'evolutionary' level which conveys new abilities and capabilities and establishes a characteristic between 'mature' and 'immature' organisations in terms of their approaches to business processes.

Maturity Models were initiated in the field of Total Quality Management (TQM) and their underlying concept is that: "*the quality of final product is largely determined by the quality of the processes used to develop and maintain it*" (Paulk, Weber and Curtis, 1995; Chen, Dib and Cox, 2014). For instance, Intel utilised an IT Capability Model to develop the IT capability as well as strengthen the IT value chain. They believe management of IT will have a direct impact on production function.

Because of the success of Maturity Models in other sectors; mainly Capability Maturity Model in Software *Engineering* Institute (SEI), researchers in the construction industry were encouraged to study the applicability of CMM within construction projects. Research on Maturity Models has been undertaken, and BIM Maturity Models have been developed. The following table (Table 1) demonstrates the four popular BIM Maturity Models within the construction industry.

Table 1: Maturity Models Developed for BIM

Maturity Models	Framework
Interactive Capability Maturity Model (NIBS 2007) for evaluating BIM information management. Interactive Capability Maturity Model taken from Building Smart (2007)	
BIM Deliverable Matrix (Alliance for Construction Excellence 2008) indicates the many types of modelling tools and focuses on digital products and deliverables BIM Deliverable Matrix taken from ACE (2008)	
BIM Proficiency Matrix (Indiana University 2009) used to assess the ability of a practitioner's skill working in a BIM environment Taken from Indiana University (2009)	
BIM Competency Set (Succar 2010) for evaluating dimensions of technology, process and policy BIM Competency Set taken from BIM Think Space (2009)	

Maturity Models	Framework
BIM Maturity Model BIM Maturity Models taken from BCIS (2011)	

The strategy paper prepared by the Cabinet Office for the Government Construction Strategy (2011) recommends the use of a BIM Maturity model to "*plan a sequence of activities to ensure that objectives to establish BIM level 2 as a standard way of working are met within the 5 year programme*". It also explains that a BIMM model can simplify the description of technologies and working practices as well as helping to clearly communicate the standards and guidance notes and how they may be applied within construction projects. Furthermore, maturity levels categorise the different types of collaborative working to "*enable a concise description and understanding of the processes, tools and techniques to be used*" (Cabinet Office, 2011). In their strategy paper, they also debate that the main goal of a BIMM should not be the software (technology) but rather 'the information and its accessibility' to the whole project supply chain.

Succar (2009) has also developed a BIM organisational hierarchy. The argument made by Succar in his research is similar to Egan's report, or built up on his statements in his 1994 report; he describes buildings in construction projects as 'unique' prototypes involving 'similar' sets of processes. Therefore, he has introduced a BIM Framework through the development of an Organisational Hierarchy and an Organisational Scale. Both the Hierarchy and the Scale are based on the concept of 'flexibility' and 'uniformity'.

Chen, Dib and Cox (2012) suggested a 'strategic framework for measuring BIMM' by undertaking a 4 stage research study: a) identifying related areas for measuring BIMM based on prior research, b) using Principal Component Factor Analysis (PCFA) on data collected from step (a) exploring the fundamental elements of BIMM, c) testing the proposed measurement model by Confirmatory Factor Analysis (CFA) and d) using data from the CFA analysis to validate the proposed model. Their results suggest that there are 5 important factors affecting BIMM measurement: Training, Process Definition and Management (PDM), Technology, Information Management and Information Delivery which had the highest score. McCuen, Suermann and Krogulecki (2012) also published a paper on ICMM and evaluated case studies from 2008 award winning BIM projects in the U.S. to assess these projects according to the ICMM tool. Their results demonstrate a continual success across these projects in the area of visualisation.

Researchers have mainly studied the technical side of BIM; its applications and standards and developing different frameworks for efficient implementation of BIM, rather than business and operational side. One of the frameworks that has been developed is the BIM maturity model as shown in Figure 4:

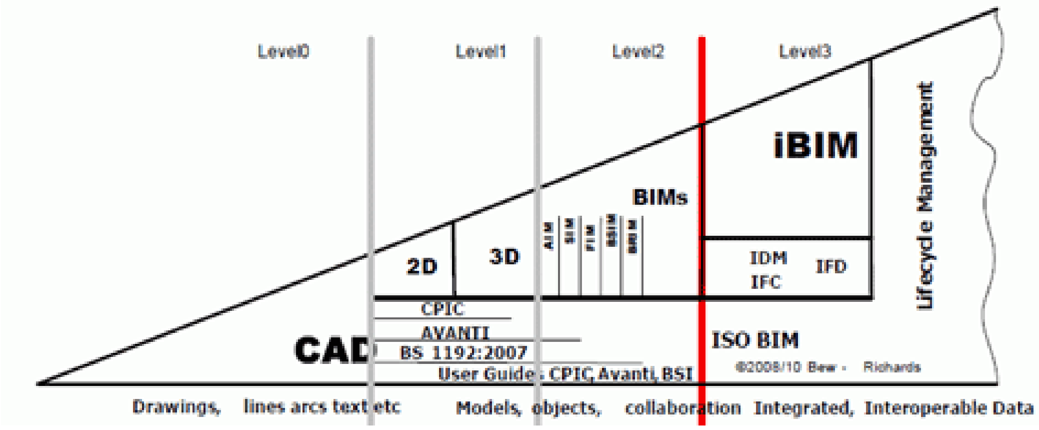


Figure 4: BIM Maturity Model (taken from BIS, Bew and Richards 2011)

This BIM Maturity Model is developed to illustrate levels of information exchange maturity within construction projects. The model is also used as a strategy to identify the supporting infrastructure required at each level for development of BIM (BIM Task Group, 2013). With regards to the BIM Maturity Model, there are a number of problems with it:

- The model utilises elements that are very specific to construction industry
- It is driven by traditional outputs of the industry which by definition are changing
- It expresses the maturity of data integration and is developed merely for implementation of BIM
- It is confusing in terms of terminology
- It is very transient and when discussed with practitioners there were considerable confusion as how they would position themselves on the matrix

However, the underlying concept that BIM is a technology for management of building information throughout the life-cycle of a project needs to be considered. Integration is not all about interoperability between two or more technologies but it is also about communication aspect, organisational structure and strategic layout. Therefore, this study applies some of the rigour from communication theory from Computer Sciences.

2.10 Common BIM Terms

Based on initiatives of researchers and based on BIM frameworks developed, there are terms created by them (RIBA, 2012):

- Lonely BIM – is a term used with regards to early level 2 projects where only one party uses BIM technologies

- Collaborative BIM - also called Social BIM and Integrated BIM, is the contrary of Lonely BIM and is a term used when all parties are utilising BIM and working collaboratively.

The UK government believes 47% of construction projects are on level 2 BIM and they require a fully collaborative 3D BIM as a minimum in construction projects by 2016 (NBS, 2013).

All the Maturity Models introduced and discussed in this thesis have different focuses on different elements of BIM. Although there have been extensive efforts to initiate and develop BIM Maturity Models; no-one has considered the 'communication' element of BIM which is vital and fundamental to a successful implementation of BIM framework and has a huge impact on a projects' success. After reviewing the literature on Maturity Models within construction industry, it is apparent that a comprehensive and concise framework of communication is a must within the industry to enable the practitioners to improve their communication protocols utilising technologies such as BIM.

2.11 Problem Overview

Since the 1990s the industry has been seeking to improve communication using Information Communication Technology (ICT). In the last three decades, there have been several studies, that aim to identify the causes of poor communication, both interpersonal communication and communication within design, and establish the weight that development of communication technologies and communication practices have on these (Guevara and Boyer, 1981; Wallace, 1987; Hill, 1995; Anumba and Evbumwa, 1999; Xie*et al.*, 2010). However, these studies have been undertaken by researchers approaching the subject from different viewpoints and with different understandings and interpretations of the problem area of communication. This has prevented the industry from achieving a shared understanding of communication and has meant that the delicate difference between communication and collaboration remains elusive. The importance of communication is better realised when its impact on industry is understood. Traditional communication methods have been criticised for inaccuracy and errors causing delays, conflicts, inadequate analysis of client's requirements, poor collaboration and co-ordination, cost and time overrun and lack of intergroup communication between key participants involved in a project with complex communication environments. Until recently this problem has been ameliorated through the use of standardised procedures based on traditional working practices (Anumba*et al.*, 1997; Latham, 1994; Eastman *et al.*, 2008; ROADCON, 2003).

Latham (1994) believes "*unless an effective communication network is established (particularly through ICT), more and more bad practice will come to light*". According to Latham (1994), ROADCON (2003), Faisol *et al*. (2006), Hill (2008) and Richards (2011), effective communication is vital to the functioning of construction projects and failing to communicate will result in low quality and productivity. However, little effort has been made to capture and understand the current communication practices to ensure they are aligned and reliable, in order to meet the future needs of BIM.

Web-based collaboration platforms have long been utilised as the means to produce, use and manage project information centrally from early concept design to detailed design, construction and handover. With the introduction of BIM and its growing popularity in the construction industry, there have been more efforts to utilise this technology to improve communication and collaborative working - now widely recognised as an effective way of addressing traditional working processes. Efforts by academics and industry professionals have resulted in BIM standards, protocols, maturity models and frameworks being developed; many of these focus on the technical aspects of BIM (Jung and Gibson, 1999; Nour, 2006; Succar, 2009; Neff *et al.*, 2010; Singh, Gu and Wang, 2011; Brewer and Gajendran, 2012). The outcome of all the BIM research undertaken in the past decade has contributed to the construction industry's understanding of the concept of BIM and has provided frameworks and maturity models as guidelines for BIM adoption. However, reliable benchmarks for communication maturity around BIM are scarce, and there is a lack of conceptual understanding of communication patterns and how they may change with the uptake of BIM (NIBS, 2007).

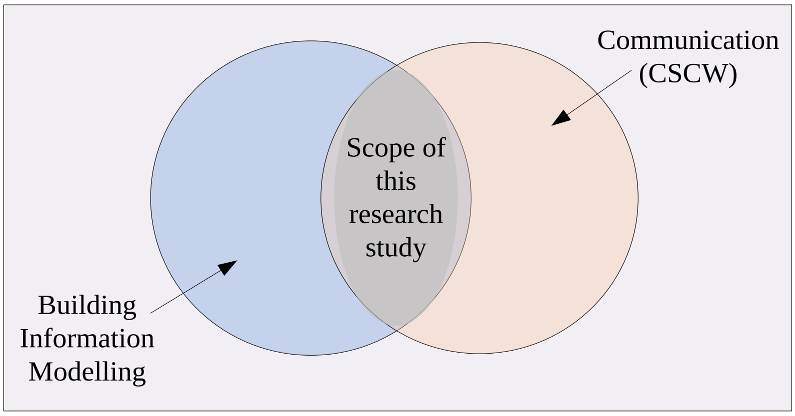


Figure 5: Scope of this research study

There are several theories related to the field of this research, in which to explore and evaluate technology (i.e. BIM) and its adoption within a social context. Some of these theories are as follows:

- Diffusion of Innovation

- Technology Driven Organisational Change
- Social Construction of Technology
- Technology Acceptance
- Computer Supported Cooperative Work
- Computer Mediated Communication
- Organisational Culture
- Change Management

Each of these theories explores one aspect of technology and each can be applied to evaluate the adoption of BIM. However the importance of communication, availability of various communication technologies and the fundamental problem of temporary and dispersed project teams suggest that Computer Supported Cooperative Work (CSCW) and Computer Mediated Communication (CMC) disciplines should not be underestimated; they can be utilised to understand the underpinning theories of communication and information exchange between geographically dispersed participants, and will contribute to enhance collaborative working. CSCW and CMC both fall under the Human-Computer Interaction (HCI) paradigm and share a lot of similar assumptions.

The construction industry moved from paper based drawings and documents archival to the use of electronic documents, not only for better visualisation but for better management and archival of these documents electronically in a more centralised and rational manner. Hence Electronic Document Management Systems (EDMS, so called extranets) emerged and became very popular. However, these systems were still dealing with 2D drawings and documents. With the emergent uptake of BIM and the increasing growth of 3D object modelling, the construction industry is now moving towards model servers and the use of intelligent models all saved in a central repository (cloud computing). On the other hand, because construction professionals are still bound to traditional practices, information models are being extracted as documents and communicated via EDMS systems and e-mail.

CHAPTER 3 - COMMUNICATION THEORIES

It is vital to adhere to a clear and shared understanding of communication within a technical environment (Dossick and Neff, 2011). Since this research study is evaluating the impacts of BIM on electronic communication patterns within construction processes and the increased development of communication technologies has provided the potential for radical changes in the use of data and information in the construction industry (Williams, Bernold and Lu, 2007) there are two major elements that need to be considered for the purpose of this research study:

1. Greater clarity on difference between data and information
2. Greater clarity on terminology and definition surrounding communication

The following sections provide a context for the research study and define and give more clarity of information and communication terminology.

3.1 Definition of Communication

Communication derives from the Latin word 'Communicate' which means "*to share or impart for a common ground of understanding"* (Rizvi, 2005). In its simplest conception, communication is a process of transmitting and articulating 'facts, ideas, opinions, emotions and attitudes' through exchange of thoughts between individuals (Perumal and Abu-Bakar, 2011). It is an inter-disciplinary notion which has different meanings and enables professionals and organisation to learn and grow.

For the purpose of this research study, communication is defined as the maturity of information exchange between individuals involved in a construction project. A team is a set of people that work together towards a common goal with specific roles and responsibilities. Based on the definition of communication, it is reasonable to say that everybody in a construction organisation, regardless of their role, is involved in a complex communication network and responsible for sending and receiving information (Dainty, Moore and Murray, 2006). It is also vital that organisations/projects have established processes that support inter and intra organisation communication (Cheng *et al*., 2001). The focus of this research study is to observe how information exchange processes are utilised and matured in a communication maturity model.

3.2 Definition of Information

The importance of information exchange has been highlighted by many public reports and researchers; ROADCON (2003), BS1192:2007 (BSI, 2007), Autodesk Data Exchange Standards (2011), UK Government BIM Strategy (Cabinet Office, 2011) and PAS 1192:2 (BSI, 2013). Despite this, information exchange has often been referred as data exchange. Since there is a difference between 'data' and 'information' from a Computer Science point of view, for the purpose of this research the term information is defined.

Information derives from the Latin word 'informare' which means 'give form to' (Biro, 2011). It is refined and useful data organised for a purpose and is presented with context. The reason for selecting information over data is that all documents in construction are useful data that are created for the purpose of achieving the project.

3.3 Theoretical Understanding

When individuals are geographically dispersed, communication is mediated through various ICT systems. Perry and Sanderson (1998) trust that technology designers are increasingly creating systems that support the work of design and engineering groups. Xie (2003) also believes that in the design domain, research and development in the application of communication technologies has increased to support more effective communication between multidisciplinary groups.

Development of groupware technologies or digital engineering should be based on comprehensive knowledge about how groups work, to be able to provide a baseline for evaluating the effects of technology for improvements. Therefore, this thesis provides an insight about communication protocols and processes and technologies that underpin BIM by examining the issue of communication through the lens of the major communication theories: Computer Mediated Communication (CMC) and Computer Supported Cooperative Work (CSCW). The focus of these theories is primarily asynchronous communication within geographically dispersed teams and they provide explanations for the concepts of communication and shared environments. The aim of this research study is to explore and attempt to extend the notion of electronic communication around BIM based on these major concepts of communication.

3.3.1 Computer Mediated Communication (CMC)

According to Wainfan and Davis (2004) one aspect of working practice is 'virtual collaboration' which they define as "*people working together who are interdependent in their tasks, share responsibility for outcomes, are geographically dispersed*".

Virtual Collaboration (VC) relies on Computer Mediated Communication (CMC) rather than face-to-face interactions. CMC is one of the major modes of VC which is increasingly being utilised in organisations to improve response time and save on costs (Wainfan and Davis, 2004). Computer Mediated Communication, as shown in Figure 6 is defined as any communication that takes place between people through the use of computers (Habil and Galea, 2002). It is believed by Walther (1997) that certain technologies in CMC can enhance the communication of people from diverse backgrounds and located in different places rather than working face-to-face.

Computer-mediated communication (CMC)	Text, images, and other data received via computer, without effective real-time voice or video images of other participants.	E-mail, chat rooms, discussion boards, text messaging, instant messaging, shared databases, application-specific groupware.

Figure 6: Characteristics of CMC taken from Wainfan and Davis (2005)

CMC is an interdisciplinary field of study that examines 'various phenomena' related to the use of Internet in communication research (Bubas, 2001). The Journal of Computer Mediated Communication has defined CMC as "*any human symbolic text-based interaction conducted or facilitated through digitally-based technologies*" (Spitzberg, 2006). It is frequently text-based, however in recent years it progressively includes drawings and images. It is either synchronous (instant messaging or chat rooms) or asynchronous (e-mail or shared databases) (Habil and Galea, 2002; Wainfan and Davis, 2005). For this definition to be true, actual people are required to be engaged in the process of message exchanging in which the medium of exchange is at some point computerised. This research study evaluates the use of synchronous and asynchronous text-based communication in distributed project teams.

3.3.1.1 Email

Electronic Mail (E-mail) is a functional principle of the Internet and one type of text-based CMC through which individuals interact (Habil and Galea, 2002). E-mail was originally designed as an 'asynchronous communication application' (Whittaker and Sidner, 1996). Ducheneaut and Bellotti (2001) and BuildingSmart (2010) argue that e-mail has become a fundamental and vital form of communication and information exchange and the main channel for distributing documentary information, supporting collaboration and personal and business interactions between individuals. Following Ducheneaut and Bellotti's work McManus *et al.* (2003) identified e-mail correspondence to be the fastest growing communication medium in the world. According to Johnson and Clayton (1998) e-mail as an internet-based technology, has been reported 'the most useful application' within construction, with 83% of respondents finding it very practical. A recent study by Ballan and El-Diraby (2011) and many presentations and discussions by Wilkinson (2012) still recognise e-mail to be the preferred choice of communication media for exchanging information.

E-mail is an asynchronous technology, which allows a written conversation as well as attachments of documents and drawings. It also enables the distribution of large number of documents and drawings to many people instantaneously. E-mail has proven to be very convenient for correspondence, exchanging information and delivering electronic messages within construction projects and has become one of the main applications for sharing and exchanging information (Johnson and Clayton, 1998; Deng *et al*., 2000; Rebolj, Magic and Babie, 2004; Derks and Bakker, 2010). It is the fastest, easiest and most efficient way to share and exchange information; therefore it has become the central part of communication workflow. It is now being utilised as an informal method of communication within and between organisations (Baldwin and Carter, 1998; Deng *et al*., 2000). Radicati and Hoang (2011) demonstrated that 40 billion e-mail were being sent every single day in 2003 and this figure has only increased. Their E-mail Statistic Report foresees an average annual growth of 7% for the usage of e-mail over the next few years and predicts that the number of worldwide e-mail accounts will increase from 3.1 billion in 2011 to 4.1 billion by end of 2015.

Figure 7 demonstrates face-to-face communication as the richest form of communication while CMC is far less rich. Media Richness Theory also allows for organisations to make communication media choices.

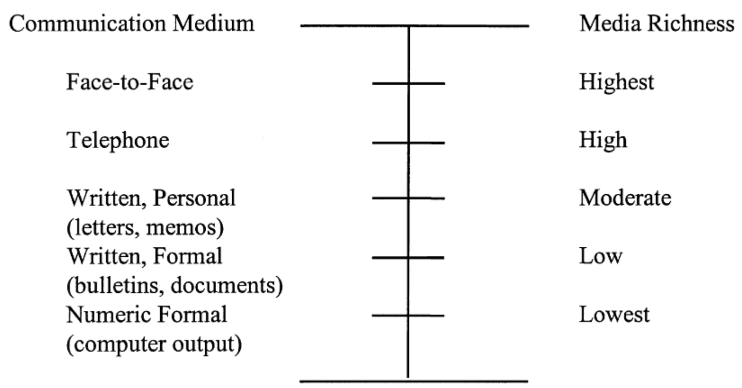


Figure 7: Communication Media Richness taken from Suh (1998)

Previous research has established that e-mail enhances the speed of decision making and facilitate information exchange (Crawford, 1982; Mackay, 1988). Sproull and Kiesler (1986) also believe that the popularity of e-mail is due to the fact that it speeds up information exchange. It is easier and faster to send e-mail than to make phone calls or construct a letter. It is also cheaper than the post and fax machines. Mackay (1988) illustrated that people deal with their personal e-mail in various ways. Later, Whittaker and Sidner (1996) verified Mackay's conclusions but also explained that e-mail is being utilised as more than just a communication tool. There have also been studies; Kerr (2003), Venolia and Neustaedter (2003) and Rohall*et al.* (2003) where e-mail server/clients have been studied and evaluated based on the e-mail threads. E-mail threads have been mapped out to see their structure and gain a better understanding of e-mail with similar attributes and how they evolve over time. Therefore the Butler Group (2004) argue that the primary driver for using e-mail is 'its instant nature' and also its capability of confirming an e-mail has been received and even read.

The Butler Group (2004) explains that "*Management of information is heavily dependent upon the aggregation of structured content and unstructured content – the latter contains the rich details that can often make the difference between data and intelligence*". The Butler Group (2004) findings are also in conformity with Deng *et al*. (2000) and Derks and Bakker (2010) who believe that e-mail has become one of the most widely used mediums in the business world. A lot of interactions that happen every day rely upon sending and receiving of e-mail and these interactions most certainly generate and contain valuable information. Yet, in the majority of organisations this valuable information remains locked into the e-mail system rather than being shared amongst people who might need it. And where the information is distributed, it is normally done in an ineffective manner, by sending long text and unnecessary attachments that hides the valuable information amongst irrelevant conversations. Hardly any thought has been given to the value of e-mail contents and how its value can be maximised (Butler Group, 2004).

In another report, Butler Group (2003) argues that e-mail has gone past its original purpose and it is now used as:

- A 'pseudo-political tool' to cover backs
- Un-required and useless CC's and BCC's
- Vast amount of information generated
- Duplication of emails by being stored on different locations
- Large distribution lists increase the duplication even more

Also e-mail charm and the extra utilities create problems for information management with numerous "*outstanding tasks, partially read documents and conversational threads*" (Whittaker and Sidner, 1996). Therefore, e-mail is now a major source of information overload due to additional utilities such as task management and archiving as well as emergent use of e-mail attachments (Mackay, 1988; Whittaker and Sidner, 1996). The problem of information overload and e-mail management, as Butler Group (2004) explains is 'a business rather than IT issue'. The adoption of e-mail has grown so much in the business world that a loss of access will cause substantial disruption and if it continues for a long time it can result in a loss of revenue (Butler Group, 2004).

The Butler Group (2003) also put forward an interesting argument:

"*I'm not suggesting for a minute that e-mail should be replaced with another technology – it is the single most powerful information management tool in use – however, my contention is that the need for sending a proportion of these e-mail could be better served through another tool. The average user will already collaborate many times a day via e-mail. Therefore, the challenge is not necessarily to get users to collaborate 'more', it is to get them collaborate more effectively and efficiently using appropriate tools*".

3.3.2 Information/ Email Overload

With the shift from paper-based to electronic-based and increase in Computer Mediated Communication (CMC) in AEC, information has become increasingly available in electronic format. "*Requests for information, change orders and other traditionally paper-based systems have evolved to the electronic realm*" (Gerhradt 2008). As a result, there has been increasing need for electronic forms of information exchange between computer applications. As discussed by academics and practitioners in a Witness Seminar Conference at Northumbria University (Childs *et al*., 2007) our reliance on e-mail has caused information overload and therefore an increase in the cost of storing e-mail in a way that only one true version of the message is stored. They continue to argue that the problem with e-mail is usually how organisations have distorted it for management purposes rather than just a communication channel. Therefore, one of the solutions to the problem of e-mail lies within people and their behaviour using e-mail.

Alvin Toffler (from Li and Li, 2011) believes "*the difficulty a person can have understanding an issue and making decisions that can be caused by the presence of too much information*" is when they are overloaded with information. In everyday language, receiving too much information is referred to as information overload.

Mackay (1988) recognised that one of the main problems with e-mail is 'information overload. Snooks (2009, p.2) also argues that "*Almost every organisation employing knowledge workers has been greatly impacted by Information Overload, defined as the mental state of continuous stress and distraction caused by incessant interruptions and the sheer volume of e-mail and other messages*."

Although e-mail and EDMS both run as stand-alone systems, there has been some integration of two systems. Merging e-mail, EDMS and workflow systems has been done to support more collaborative working. However, anecdotal evidence shows that volume of communication and information has increased with e-mail and electronic communication systems technologies, while the amount of collaboration has decreased. Anecdotal evidence also shows that the integration of e-mail and EDMS has overwhelmed recipients with irrelevant information coming through e-mail and has caused information overload.

With the wide spread use of ICT and new technologies, a large amount of computerised information has begun to overwhelm project participants' ability to understand and process the information (Mao, Zhu and Ahmad, 2006). Fast growing development of ICT and increase in the amount of information being created has brought into focus the problem of information overload. Figure 8 illustrates the cause and impacts information overload. Project participants find it ever more difficult to cope with the amount of information they receive and the side effects of their actions towards it.

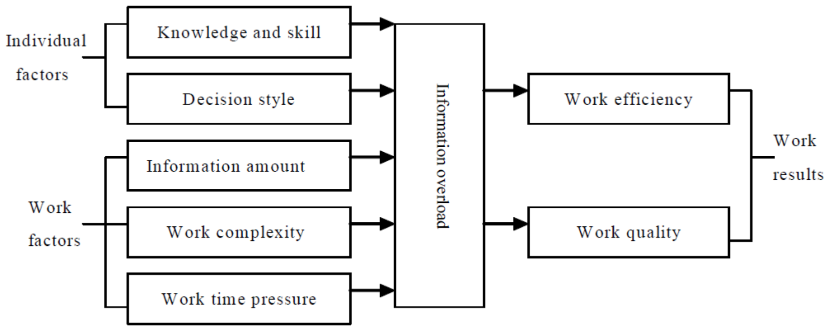


Figure 8: Cause and Impacts of Information Overload taken from Li and Li (2011)

E-mail has grown quickly over the years and has become a central part of many professional organisations. Notifications, discussion items, allocated tasks and other task related activities which come through EDMS systems overload e-mail users with unnecessary information, lack of information, incomplete information. A study by Xie *et al*. (2010) also proves that information overload is common within different organisations causing ‘unnecessary stress and inefficiency’. Their results demonstrated that everyone who participated in their survey complained about receiving irrelevant information and because of that useful information was ignored. Guevara and Boyer (1981) identified overload to be one of communication problems. According to Sommerville and Craig (2006) information overload could have an effect on ‘a person’s ability to take it all in’.

Ease of use of electronic documents and increase in availability of information has allowed practitioners to exchange more information and therefore create an overload on people. Thus, it is vital to ensure that increased exchange of information does not create the following problems: (Kangari, 1995)

- Unrelated or inappropriate information
- Incomplete information (which reduced the value of information)
- Unnecessary amount of information (information overload)
- Poorly structured and organised information

Ahmad, Russell and Abou-Zeid (1995) and Tesfagaber and Bouchlaghem (2004) recognise the wide-spread use of ICT within construction and argue that because of this growth, means of generating information has changed and information has become increasingly available in electronic formats. Thus, there is a growing need for exchange of electronic information between project participants. However, methods of sharing and exchanging information across project teams have not fundamentally changed (Ahmad, Russell and Abou-Zeid, 1995).

Groupware Support Systems (GSS) and Computer Supported Cooperative Work (CSCW) - also known as collaborative software - are examples of CMC. They are usually referred to as technical information systems that can be implemented on the Internet and provide a single communication platform to help a group of users, allowing them to work cooperatively while located remotely. This enables them to achieve common goals and solve problems. Information systems that facilitate real-time collaboration are called ‘synchronous’ groupware which can include: sharing of calendars, e-mail handling, shared database access and other activities (Fjermestad and Hiltz, 2000).

3.3.3 Computer Supported Cooperative Work (CSCW)

Siebdrat, Hoegl and Ernest (2009) refer to geographically dispersed teams as Global Virtual Teams (GVT) and explain that team members in a GVT rarely or never meet face-to-face (Cascio and Shurygailo, 2003; Wainfan and Davis, 2005; Siebdrat, Hoegl and Ernest, 2009). Zigurs (2003) describes GVT to be a team that is dispersed by “*geography, organisation,* *time, culture, language*" and the main form of corporation is based on using communication technologies.

Mills (2003) argues that "*few contest the claim that modern information technology, supported by computers and communications, contributes to a dramatic improvement in productivity and effectiveness among individuals engaged in a wide range of tasks*". Therefore, concepts such as CSCW, illustrated in Figure 9 are utilised to provide improvements for individuals working together in a conscious way as a project team (Mill, 2003).

The review of the literature confirms that this type of cooperation raises several issues, that may well be found in collocated teams but they will be aggravated due to dispersion (Hansen, Hope and Moehler, 2012);

- Trust
- Coordination of Work
- Conflict
- Culture
- Communication Technology

Construction projects and their cooperative work nature fit perfectly with the Computer Supported Cooperative Work concept and CSCW matrix as illustrated in Figure 9.

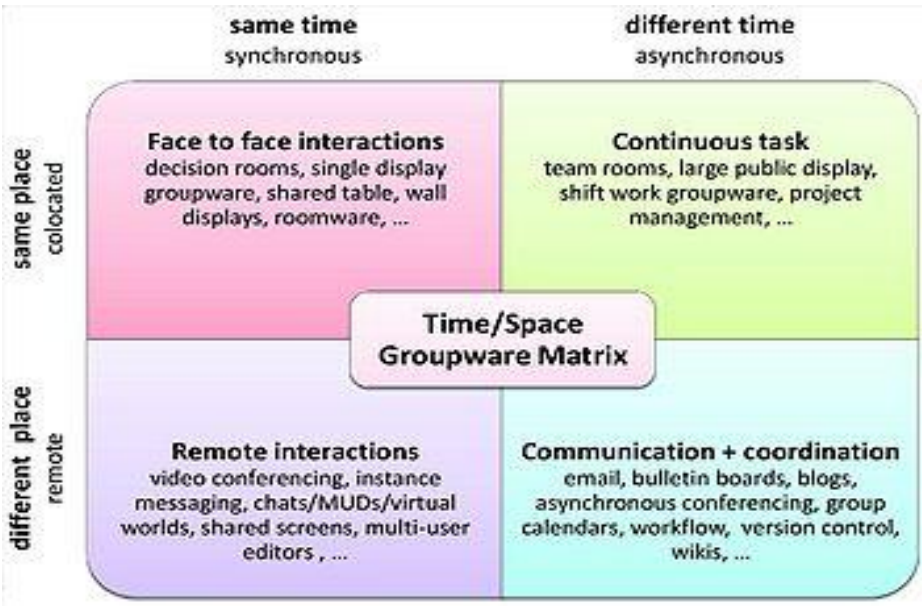


Figure 9: CSCW Matrix taken from Mill (2003)

In a construction project there might be participants:

- Who are at the same place (co-located) and same time (synchronous) through face-face interactions,
- Who are at different places (distributed) but working at the same time (synchronous) though remote interaction,
- Who are at the same place (co-located) but working at different times (asynchronous) through continuous task,
- Who are at different places (distributed) and working at different times (asynchronous) through communication and coordination,

And to address the challenges listed above, the industry has introduced, within BS1192:2007, PAS1192-2:2013 and PAS1192-3, the concept of a Common Data Environment (CDE). The term CDE, which is closely aligned to the principles of Computer Supported Cooperative Work, has its roots in various project collaboration efforts (as part of the AVANTI projects) that were developed during the early developments and implementations of BIM to form an approach to collaborative working. BS1192:2007 and PAS1192-2:2013 define the functional and non-functional requirements of the CDE during the design and construction stages of a project and PAS1192-3 describes how the CDE should be utilised during the operational phase.

The guidance in these standards describes the Common Data Environment as a designated environment that should be managed through specified controls, states and processes within integrated systems. Predefined controls and processes ensure that information is shared efficiently and collaboratively between all members of a project team, and in a controlled and managed manner. It is applicable to all those who need to make decisions on building or infrastructure assets, at any point in its lifecycle, and those who are involved in the design, construction and maintenance of assets. Hence, the CDE defines the steps for delivering progressive, reusable project and asset information in an assured, coordinated, quality controlled and auditable fashion. By defining both the state and suitability of information the process ensures that it is clear who should have access to information and what it is suitable to be used for. The CDE may comprise of one or more systems, each supporting a consistent collaborative approach.

Ramage (1996) argues that evaluation of ICT and Information Systems (IS) is difficult due to the various participants and multiple perspectives involved in ‘using’ the technology. He expands on this argument by saying that the evaluation of CSCW systems is even more difficult because participants involved work together 'via' the technology. Evaluation of CSCW systems refers not only to technology but rather to the whole collection of people, projects, organisations and their working environment as demonstrated in Figure 10.

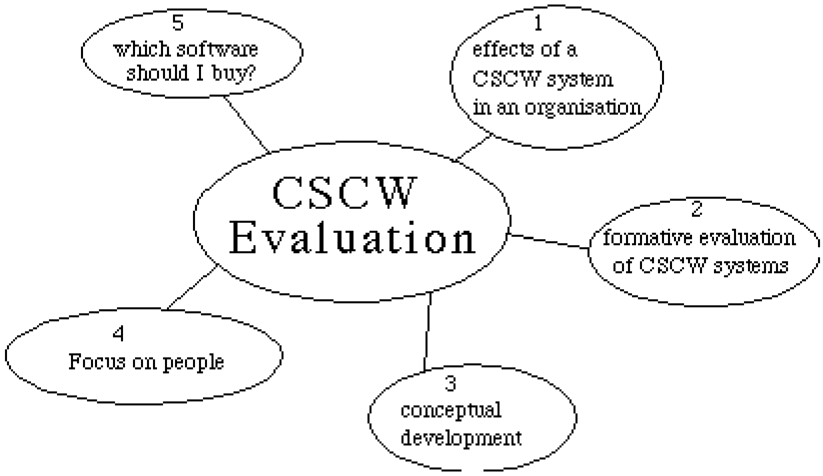


Figure 10: Five types of CSCW evaluation taken from Ramage (1996)

This means any organisational or personal conflicts as well as organisational culture will directly affect how these systems operate.

3.4 CMC and CSCW review in Construction Industry

In the last two decades, both industry professionals and researchers in academia have been investigating and proposing different communication technologies and working processes to address the issues surrounding collaboration within construction projects. The impact of these new technologies has been highlighted by different researchers and from different viewpoints: Brochner (1990) discussed the impact of ICT on the structure of construction projects; Acar*et al.* (2005) studied the use of ICT within small and medium-sized construction firms; and Peansupap & Walker (2006) and Harty (2010) explained Diffusion of Innovation within construction projects.

According to Emmitt and Gorse (2003) the literature on communication within construction projects goes back to the 40's. However, due to the popularity and the uptake of research studies around BIM in the 80's and for the purpose of this research study, the body of evidence from researchers observing communication technologies and communication failure has been reviewed and investigated in various studies since the 80's.

Guevara and Boyer (1981) studied the causes of poor communication in nine different construction organisations to understand the contribution of effective communication to the success of an organisation. In order to assess and measure the effectiveness of communication, they used multiple regression, a quantitative method developed by Roberts and O'Reilly in 1974. Using multiple regression, they identified which communication variables were affecting the communication problems and to what extent. The results were categorised into four different problems; distortion, gate keeping, overload and under load. They recognised the problems to be common in all organisations and the whole industry. Guevara and Boyer (1981) continue to describe communication systems as the 'central nervous systems' in a project which enables hundreds of people to do multiple tasks in an "*integrated and orderly manner and to coordinate their efforts and skills towards a common goal*". Anumba and Evbumwan (1999) share the same opinion as Guevara and Boyer and believe this is particularly evident in the construction industry. Guevara and Boyer's study was possibly the first time that quantitative methods had been used to measure and identify communication problems in construction.

Before the work of Guevara and Boyer, other studies on improving the communication in construction were undertaken. In 1962 a governmental report by Emmerson emphasised the importance of effective communication and information sharing amongst project participants. In one study started in 1996 by Sonnenwald to focus on information sharing within the design phase, a descriptive model was developed to illustrate the communication networks throughout the design process. Guinan (1986) studied interpersonal communication techniques and their relation to job performance using conversational analysis and performance surveys. Wallace (1987) studied the influence of design team communication content on the architectural decision making process in the pre-contract design phase. Curties *et al.* (1988) studied the problems of designing software systems by interrogating 17 large projects to understand software productivity and quality through their impact on cognitive, social and organisational processes.

A different study by Bowen and Edwards (1996) looked into communication aspects of quantity surveying during the design phase to develop more effective cost planning. Results of interviews and observations by Sonnenwald (1996) also prove that communication is the crucial process for design collaboration, and design and construction processes are dependent on the communication processes. Although the construction industry is highly fragmented with project teams geographically dispersed professionals in construction have been successfully communicating via the use of IT and Internet for many years (Anumba *et al*., 1997).

Baldwin, Thorpe and Carter (1999) studied the issue of Information Exchange (IE) within projects constructed under alliance agreements. They described a case study in which IE was utilised to facilitate information sharing that follows a review of the background to IE. Details of this case study were reviewed and the benefits of IE assessed and the following benefits of using IE were identified: guaranteed delivery of data; improved quality of data; reduced data handling; improved communication between the alliance partners; and reduced risk of project delay.

There have not been many studies investigating formal and informal communication processes within project teams. Hill (1995) was one of the few who investigated this difference and made a comparison between formal and informal communication effectiveness. Similar to Boyd and Wild (1999), Hill identified informal communication as the supportive structure that 'gets the job done'. She believed that the informal communication process supports the formal system in a project. Hill also advised that there is a lack of research and perception about informal communication processes. (Murray *et al.*, 2000).

According to an empirical study done by Knoop *et al.* (1996) there is a positive correlation between design performance and the amount and content of communication. Soon after, Thomas *et al.* (1998), as part of the Construction Industry Institute (CII) research team continued to work on the hypothesis that communication is essential to the success of construction projects by; a) investigating the relationships between projects success and communication, b) identifying critical communication variables and c) measuring projects communication effectiveness. Thomas *et al.* (1998) collected data using a questionnaire, from 38 construction organisations for 72 projects geographically dispersed in 8 different countries, allowing them to study and analyse the relationship between communication effectiveness and project success. Variables identified were categorised as follow:

- Accuracy
- Procedures
- Barriers
- Understanding
- Timeliness
- Completeness

Based on the variables that emerged from the data set, the correlation coefficient between communication and the success of construction projects was 0.71, which clearly signify a positive relationship between them. A ‘Compass’ assessment tool was developed based on the above variables to measure and monitor problem areas in communication which then will assist to improve team communication (Thomas *et al.*, 1998). Even though communication variables were identified in U.S.-based construction organisation, the projects were worldwide and Murray *et al*. (2000) research specified that these variables were also critical in the UK construction industry.

Such studies identified communication problems and these problems contributed significantly to poor team communications, which led to Mead’s suggestion in 1999 that variables affecting communication should be included in the communication research of a construction project. Anumba and Evbuomwan (1999) also proposed an integrated framework for effective communication of all project information during all stages in a project’s life-cycle. They recommended that “*integrated design and construction processes were underpinned by a variety of design tools and techniques by appropriate databases and knowledge bases*”.

Another form of communication analysis method which has quickly developed over the last two decades is the analysis of a project’s communication social networks. This form of analysis method is a type of social network analysis, and its focal point is the communication patterns developed between professionals and organisations. This method is commonly used in sociology and communication science and assists to achieve a high level description of project communication networks through relational data (Garton, 1997).

One of the later studies undertaken by Perumal and Abu-Bakar (2011) investigated communication planning to establish and improve standardisation that enhances the communication process for better document management. An earlier study by Esposito and Macchi (2009) addressed the issue of contents and structure of communication processes in building design process by analysing the communication processes in an airport passenger terminal project run in Italy. The analysis was conducted via a structured questionnaire to define the basic elements to build a User Profile for communication processes in a project team.

There have also been explicit methods and models developed to explain and simplify information flow between professionals to enhance communication effectiveness. For instance, “*IDEFO based modelling of information flow, the design structure matrix analysis, ApePT and multi objective-built criteria methods (*Austin et al*), and the design* *process model of detail building design. In addition, a design process model of concept building design has been developed by Pendlebury (1998)*" (Xie, 2003).

Xie *et al.* (2010) investigated communication issues within construction design and how they can be improved by conducting a questionnaire survey. By conducting a further case study, they gained further insights into the issues identified and demonstrated how new procurement methods such as partnering could influence multi-team communications in construction design. Finally, Gul, Wang and Cagdas (2012) explored the use of asynchronous and synchronous communication modes during design activity in a remote context as part of a bigger research on collaborative virtual environments in education.

One of the few researchers who have clearly described and highlighted the concept of CSCW within construction is Mann *et al.* (2008), who argue that CSCW in construction involves "*the interaction within and between diverse cross-functional teams of individuals who may be scattered over a wide geographic range, therefore collaboration, coordination and co-decision making are critical to a successful design*". CSCW adopts a collaborative information sharing approach between project participants which could assist to bring various disciplines and experts together so that they can use their knowledge and work more effectively regardless of location or time (Miao and Haake, 1998). A collaborative approach here is defined as a set of working processes where individuals share a common objective and work together to accomplish it. The objective would be an end product (unified entity) resulting from all individuals' contributions (Miao and Haake, 1998).

Researchers and practitioners have been improving communication (Cheng *et al.*, 2012) by setting up communication systems such as Total Information Transfer System (TITS) as a project management tool for information sharing which determines the roles of representatives from organisations that play the role of communicating with other stakeholders.

3.5 Critical Review of CMC and CSCW

All of the discussed studies have emphasised that effective communication is vital for project success. But as demonstrated, most of the studies have focused on the technical aspects of communication and communication technologies and new communication technologies have been implemented in order to achieve improved communication between distributed project teams (Perry and Sanderson, 1998; Wikforss and Lofgren, 2007). Although the research methodologies and models developed in these studies have investigated and explained communication processes from different perspectives, the basic element of communication which is the relationship between a sender and a receiver (a context in which communication occurs) is the same. However, as (Xie, 2003) also mentions, an important step in improving team communication is to accurately identify and measure communication effectiveness (Thomas *et al*., 1998).

The transition of the construction industry to the computer- integrated era requires the development and acceptance of collaboration technologies for all steps of a construction project from design, through construction process planning to project execution and management. CSCW is an adequate approach that the construction industry, with its fragmented background, can apply to unstructured data/information (Butler Group, 2004). Construction has been pushed to implement more efficient ways of managing information. At the same time, the growth of unstructured content, which accounts for around 80% of an organisation's total data, has resulted in a demand for Enterprise Content Management solutions to help manage and reduce the amount of unstructured content stored. As the volume of data increases, the process of searching and retrieving an individual item of information will slow down. Although collaboration tools were targeted for internal use, there is also now the realisation that they can provide external collaboration with other stakeholders (Butler Group, 2004).

As far as this research study is concerned, there are only a few numbers of studies that have directly referred to concepts such as CMC and CSCW and have utilised these theories as an underlying concept to understand and explain the social phenomena that individuals are placed in within construction project teams. Most of the literature is emphasising; the importance of communication, problems concerning communication, importance of improved communication within design, identifying causes of poor communication, measuring the effectiveness of communication and designing new collaborative frameworks. The focus of these researchers, has however been on both the client side and the supply side during the whole project life-cycle. All researchers have indicated that knowledge about CMC theories is vital for collaboration via the Internet.

It has also been observed that most of the communication studies within construction go back to the late 80s and early 90s. It seems that researchers have assumed that with the adoption of new digital engineering technologies including BIM, the problem of communication has disappeared altogether and the focus has shifted more towards the concept of collaboration and collaborative working. Hence 'collaboration' is nowadays a buzz word in both the industry and academia. But what has been forgotten is that communication is the vital key to collaboration, and communication must be well established and utilised precisely in order to achieve a collaborative environment. It appears that there is lack of understanding and clarity on terminologies surrounding communication within construction industry. Therefore, it was vital for this research study to give clarity to the term communication and distinguish the difference between communication and collaboration.

Much of CMC research has concentrated on comparing a CMC medium with face-to-face communication, comparing different CMC media for a specific task, technical attributes of different communication media, how individual users interface with their computer and how groups interact online. However, as ICT evolved and communication via computer networks expanded, research and analysis need to go beyond studying single users and groups to examining virtual communities (Wellman and Gulia, 1997). Limiting research scope to individuals and small scale groups does not describe the combination of software, hardware and people that supports CMC and simplifies the ‘complex social networks’ that computer networks support (Garton, Haythornthwaite and Wellman, 1997).

Much research has been undertaken in the field of CSCW to study and evaluate how individuals within a project team communicate with each other. Mills (2003) has discussed in his paper that CSCW has been recognised as a highly diverse discipline by social scientists which includes ‘artificial intelligence, computer science, psychology, sociology, organisational theory, anthropology, network communication, distributed systems, user interface design and usability’. Nevertheless, much of the focus has been on studying and developing an understanding of the practical limitations of work practices; providing computer tools to improve working processes by ‘articulate work’; and improving organisational structure and operational procedures (Mills, 2003; Sward, 2006; Randall and Salembier, 2010). Articulation work embraces development and management of a unified and shared information resource and workflow management. To support articulation work, CSCW researchers have invented six main features in design area: communication, configuration, coordination, information access, interaction and usability (Mills, 2003). Communication is one of the key design areas within CSCW (Table 2), and its key features include: asynchronous, synchronous, data, shared, structured and unstructured which are the interest and focus of this research (Mills, 2003).

Table 2: Five CSCW design areas and some key design features in each

Design Area	Key Features
Communication	Asynchronous, audio, data, private, shared, structured, synchronous, text, unstructured, video
Configuration	Adaptation, composition, evolution, extension
Coordination	Access control, concurrency, consistency, delegation, scheduling, versioning
Information Access	Distribution, filtering, retrieval, structure
Interaction	Attention management, awareness, context management, relationship establishment and maintenance
Usability	Boundary crossing (cyberspace, physical space, logical space), cross-device interaction, cross-mode interaction

It is very common for social scientists who are working in the field of CSCW to adopt two main viewpoints. One view is technology-centric, which emphasises the development of computer systems that meets the requirements of cooperative work groups to better support individuals working cooperatively. The second view is work-centric, which focuses on analysing work processes and describing people's behaviour working together in a group to improve computer systems design to better support group work (Mills, 2003).

Although such in-depth analysis and understandings of working processes are considered crucial, this research study focuses on the communication channels and ways in which participants exchange information in a group (synchronous vs. asynchronous), problems with these channels (structured vs. unstructured) and how that might change with BIM as a collaborative platform (data and shared models), as well as considering people in a Computer Supported Cooperative Work environment. CMC and CSCW are viewed from a support perspective for dispersed project teams, their working processes and communication technologies, where the role of the groupware system, i.e. BIM is to support and improve communication patterns as they are practiced. So the social, organisational and technical contexts in which communication systems are embedded are brought under close inspection.

3.6 Critical Review of BIM and Research Hypothesis

Existing literature suggests that there has not been sufficient research in evaluating and systematically defining communication as a form of interaction as well as electronic communication patterns in general and how they may be affected with adoption of BIM within construction project teams. One of the reasons for incorrect perception and usage of electronic communication is the lack of research undertaken in this field. Lack of conceptual understanding of communication patterns will limit the knowledge to develop a theoretical framework for implementation of a successful collaborative environment. Although various researchers have argued and agreed that effective communication is vital for a project's success, no specific research has focused on electronic communication patterns of construction projects. The same applies to BIM; even though literature suggests that BIM frameworks are being developed by researchers and BIM models are promising integration, interoperability, improvement in web-based collaboration and communication, there is no evidence in the industry. Major research and arguments in academic and professional literature on BIM, including white papers and governmental reports, focus on technological aspect of technologies supporting collaboration.

The need for further research in communication technologies from an organisational viewpoint has been highlighted by Wikfross and Logfren (2007). They argue that organisations are very excited about improving collaborative working via implementation of appropriate communication technologies to place themselves in a competitive edge. Nevertheless, they often get carried away with these implementations without conducting a serious assessment of the specific framework in which it may be placed or the crucial effects it may have on people and working practices. The evidence of this argument can also be seen in the construction industry where emerging ICT has enabled the industry to create computer supported environments but firms adopting these technologies have not been successful in achieving the full benefits of their implementations (Erdogan*et al*., 2008). Erdogan*et al*. (2008) explain that based on their findings most of ICT investment failure is due to 'change, implementation, human and organisational factors, roles of the management and end users' aspects of ICT adoption rather than technical factors'. They continue to argue that the main problem within construction projects is not 'lack of technology' but rather 'a lack of awareness' of how to fully implement and utilise technology within an organisational context.

As discussed earlier in this chapter, BIM as a technology provides a consistent way of handling structured data (everything known about an asset) in a shared and centralised database through the lifecycle of project (Isikdag& Underwood, 2010; Arayici*et al*., 2011). BIM applies intelligent relationships between components in the model and enables the visualisation and development of 3D spatial models of buildings and intelligent objects. Employment of a single 3D model for delivery of information to the right person at the right time helps reduce project fragmentation, costs, duplication and enable an interoperable process for practitioners to work collaboratively (Eastman*et al*., 2011).

Neff *et al*. (2010) have clearly stated that the current practice within industry has mainly adopted BIM because of its technological advances and therefore organisations still remain divided which in theory is not the aim of BIM adoption. Therefore, the aim of BIM to bridge the gap between interdisciplinary teams has failed. This failure is not only technological but also organisational and social. It has been observed by Neff *et al*. (2010) that terms collaboration and communication within construction industry is not fully understood and there is a need for further research to clarify these terms, especially within the new BIM environment.

Arayici*et al*. (2011) also argue that "*BIM incorporate a methodology based around the notion of collaboration between stakeholders*". Sebastian (2011) and Grilo and Jardim-Goncalves (2010) also suggest that BIM is providing collaborative processes in multidisciplinary teams. Arayici *et al*. (2011) continue to argue that this collaboration could reduce the fragmentation that exists in the industry. Also according to ASHARE (2008) BIM promises to bring more collaboration between dispersed design and construction teams and has already proven to "*increase collaboration between professionals and has allowed stakeholders to better understand buildings and more effectively participate and contribute*". However, Sebastian (2011) strongly believes that the effectiveness of BIM for an effective collaboration has been undermined due to professionals in construction industry viewing BIM as an IT tool and not as a process.

One of the main benefits of utilising BIM is to create and input into a single model and then take snapshots or have representations and extractions from this single model (Arayici*et al*., 2011). This should reduce the project participants' dependence on documents and drawings to communicate design ideas (Crotty, 2012). However, it has been observed during data collection of this research study that BIM as a single and shared model is not currently being utilised in most project teams. Since BIM is not being used as a single model, professionals are using BIM as a number of disconnected information models (lonely BIM) exclusively designed for multi-disciplinary design teams. Because BIM allows automatic updating, information models get updated automatically every time there is a small change to reflect the changes. The updating process has resulted in additional documents and drawings to be created. Since practitioners are still using the conventional ways of coordination, documents and document versions need to be monitored, managed and approved by the project manager and because of the mistrust culture in construction (due to liability issues) all documents extracted from the BIM model must be available to all stakeholders. This has created more documents for participants to exchange and distribute amongst the project team. Based on these findings, it has been hypothesised that: implementation of Lonely BIM combined with the use of traditional working practices will increase document correspondence within construction projects.

CHAPTER 4 - RESEARCH METHODOLOGY AND DESIGN

This chapter presents the methodology and design, application and justification for the selected methodological approach, data analysis, scope, limitations, validity and ethical considerations. This research project has adopted Crotty's social research process to explain and justify the research methodology adopted for this study. According to Crotty (1998) there are four elements in developing any research proposal:

- *Methods* which are techniques and procedures used to gather and analyse data
- *Methodology* which is research design or strategy which links the methods
- *Theoretical perspective* which is the philosophical context for the research design
- *Epistemology* which is the paradigm of social research and theory of knowledge embedded in the theoretical perspective

The following sections will expand on the above four elements in more detail, starting with the Theoretical Perspective and Epistemology.

4.1 Theoretical Perspective & Epistemology

"*Research is to see what everybody else has seen, and to think what nobody else has thought*"

Albert Szent-Gyorgyi

Researchers (individuals in general) have different beliefs and perceptions of the materialistic and spiritualist world, what happens in the world and how they are relevant to each other. Therefore, no research is conducted in the same way and the way in which research studies are undertaken differ from one another. As a result, it is important to consider different paradigms when conducting a research to better understand 'why' the researcher has adopted the methodological approach and to ensure the researcher's perceptions and biases are understood and minimised. Flowers (2009, pp. 1) perfectly explains why research paradigms are extremely significant and important to Social Sciences:

> "*Since the humanistic element introduces a component of 'free will' that adds a complexity beyond that seen in the natural sciences and that different paradigms 'encourage researchers to study phenomena in different ways', going on to describe a number of organisational phenomena from three different perspectives, thus highlighting how different kinds of knowledge may be derived through observing the same phenomena from different philosophical perspectives*."

Patton (1990) defines paradigm as a 'world view'. A research paradigm is the foundation of the research and acts as an intellectual framework which enables the researcher to identify and clarify their beliefs about how the world works, i.e. reality, how the complexity of the world should be understood and studied i.e. methodology, and how to think about the world and extract knowledge from it based on these beliefs i.e. ethics and knowledge creation (Creswell and Plano Clark, 2007). Many researchers have categorised these beliefs as: (Patton 1990; Tashakkori and Teddlie2003;Creswell and Plano Clark 2007; Bryman 2012; and Pickard 2013)

- Ontology which is 'the science of being' and deals with what exists and what is real.
- Epistemology which is 'the science of knowledge' and deals with the relationship between reality and research (creation and the process of creating knowledge).

According to Pickard (2013) a research paradigm involves a methodology. A methodology is the angle that researchers take to attempt the research question or the hypothesis and is made up of two elements; a) philosophical forces which drive the research and b) methods including techniques, tools and procedures utilised to carry out the research. Therefore, to explain and justify how the methodology for this research study was selected there are two elements to consider; research philosophies and research methods.

4.1.1 Research Philosophies

Discussions from the previous section led to the philosophical foundations of this research study. Research philosophies are generally categorised into three types;

4.1.1.1 Positivism

"*Truth is Truth. To the end of reckoning.*"

William Shakespeare

Positivism is a philosophy which is objective and the emphasis is on authentic and reliable knowledge. Positivists believe real knowledge only comes from positive verification of theories and causal explanations of phenomena through direct observation and a solid scientific method (Fekede, 2010). Positivism is concerned with quantifying 'social phenomena' and rational and logical approaches and strongly believes that there is only one solitary objective reality to any research despite of the researcher's beliefs (Fekede, 2010; Creswell, 2009; Pickard, 2013). They have argued that observations with regards to social phenomena “*should be treated as entities in the same way that physical sciences treat physical phenomena*” (Burke, Johnson and Onwuegbuzie, 2004, p.14). Positivism merely focuses on facts and relationships among variables using quantitative methods; statistical analysis, surveys and mathematical techniques are the main research approaches adopted by positivists.

Positivist philosophy underpins quantitative research methodology (Creswell, 2009) and deductive reasoning (Bryman, 2012). Deductive reasoning is a ‘top-down’ approach where a research study starts with a theory or a generalised assumption and works its way down to specific observations and details and leads to confirming or rejecting the theory (Saunders, Lewis and Thornhill, 2007; Bryman, 2012).

Even though quantitative research has been identified as a solid base of research, because it is underpinned by positivism philosophy, and has the ability to use large data sets to test and validate theories and generalise research findings (Burke, Johnson and Onwuegbuzie, 2004), it has limitations too. The main limitation highlighted by some researchers, is that it fails to distinguish people from ‘the world of nature’ and the researcher is not often separate from the object of observation (Creswell and Plano Clark, 2007; Bryman, 2012; Pickard, 2013).

4.1.1.2 Interpretivism/Constructivism

“*Any fool can know. The point is to understand*”

Albert Einstein

Interpretivism/Constructivism is a philosophy opposite to positivism, which states there can be more than one reality (several realities) and there are different approaches to emphasise these realities in social and cultural aspects (Denzin and Lincoln, 2011). Interpretivism is linked with human sciences and is concerned with ‘understanding’ (Crotty, 1998) and deals with studying the social phenomena (Pickard, 2013). Interpretivists aim to understand meanings, reasons and other subjective experiences and interpret human behaviour and their attitudes within time and contextual bound (Creswell and Plano Clark, 2007). Interpretivist philosophy underpins most qualitative research methodologies and inductive reasoning. Essential elements of qualitative research designs are theoretical framework, inductive analysis and forming a tentative hypothesis (Pickard, 2013). When applying qualitative analysis, the purpose is to arrive at a set of assumptions or a hypothesis using the inductive analysis process.

Inductive reasoning is a ‘bottom-up’ approach where a research study starts with an idea or a specific observation and works its way up to explore and discover specific patterns and leads to general conclusions and tentative hypothesis (Saunders, Lewis and Thornhill, 2007; Bryman, 2012).

Because qualitative research enables to capture participants' experience and perceptions as well as generating rich explanations of complex social phenomena, it has been widely used in recent decades (Saunders, Lewis and Thornhill, 2007; Bryman, 2012). However, qualitative research is limited in its ability to generate predictive frameworks or to induct a generalisation for large populations.

4.1.1.3 Mixed Methods

"*Everything we hear is an opinion, not a fact. Everything we see is a perspective, not the truth*"

Marcus Aurelius

Mixed methods combine qualitative and quantitative approaches of data collection and data analysis within the same study to produce a combination of experiential and statistical results (Symonds and Gorard, 2008). Mingers and Gill (1997) explain that a couple of decades ago researchers had to make a choice between a hard-system realist or a radical humanistic but you could not be both or construct your own view on an stance. Quite recently, Bryman (2012) and Sweetman, Badiee and Creswll (2010) have also discussed that there are arguments against mixed methods because researchers believe that research methodologies must be linked to either one of the paradigms and methodologies cannot be mixed. Nevertheless, mixed methods have become popular in recent years due to recognition of some limitations and weaknesses in both qualitative and quantitative methods (Mingers and Gill 1997; Teddlie and Tashakkori, 2003). Pickard (2013) believes mixed methods are a combination of methodologies and fall within the post-positivism paradigm. Mixed methods encourage the use of different methods and also encourage researchers to use multiple world views or paradigms (Creswell and Plano Clark, 2007).

Because of the narrow focus of qualitative research, it can expose information about experiences, perceptions and context regarding people and their culture and the environment of the study. Quantitative research on the other hand is not suitable for specific reasons or explanations and is appropriate for inducting generalisation for a large group of people or a large data set. As a result, both research approaches are complimentary when utilised together. Both qualitative and quantitative research have strengths that if combined the strength and effectiveness of research will be maximised. It is argued, in the context of this research study that mixed methods provide a better and a more complete understanding of human behaviour and social phenomena (Creswell and Plano Clark, 2007; Jeanty and Hibel, 2011).

Major types of mixed method designs are; Tri-angulation Design, Embedded Design, Explanatory Design and Exploratory Design (Creswell and Plano Clark, 2007; Al-Hamdan and Anthony, 2010; Pickard, 2013). Tri-angulation is used to directly compare statistical results from a quantitative study or validate quantitative results with qualitative data. Embedded Design is used in large quantitative or qualitative studies to answer the research problem.

Explanatory is a two stage design in which the qualitative data helps explain the quantitative results. The Exploratory Design is contrary to Explanatory Design; results of the first stage help developing an assumption which can then be validated and tested using quantitative analysis.

There are also different procedures when it comes to collecting data; concurrent, transformative and sequential. Concurrent procedure allows for data collection independently at the same time. Transformative procedures place an emphasis on social justice. Sequential procedure enables the researcher to elaborate on and expand the findings of one method with another.

4.2 Approach to Research Methodology and Methods for this Study

“If we knew what we were doing it wouldn’t be called research.”

-Albert Einstein

This research project has investigated the problem of communication within construction projects and how the introduction of BIM can further challenge established ways of working and alter existing methods of communication. Chapter 2 identified that there was insufficient information about the use of e-mail within construction projects and the lack of research about electronic communications in general, was tangible within the field. At the same time, BIM was increasingly being adopted in working practice and promised new ways of working and an improvement in collaboration within the design and construction teams.

The aim of this research therefore is to investigate the impacts BIM would have on communication patterns of construction projects, based on anecdotal evidence that users are overloaded with information coming through e-mail; information which is inaccurate, incomplete and in some cases missing.

The main objectives, as illustrated alongside research steps in Table 3, are to:

- To develop a conceptual map of current communication practices to visualise the existing patterns with reference to building processes
- To explore industry professionals' understandings of BIM and current methods of working in order to determine the relationship between project characteristics and level of electronic communication through analysis of real project communication data
- To understand electronic communication patterns over time through data mining and statistical analysis
- To develop a communication maturity model (4C) according to which communication patterns can be predicted and managed during implementation of BIM

The research design was selected based on the nature of the study and adopted a mixed method strategy; combination of qualitative and quantitative methods (Bryman, 2008). Figure 11 demonstrates the research timeline including the research strategy, methods and techniques. The initial stage of the research (qualitative stage) was largely exploratory to observe 'what' is happening and use inductive reasoning to generate a hypothesis and was made of two research techniques; pilot study and focus groups.

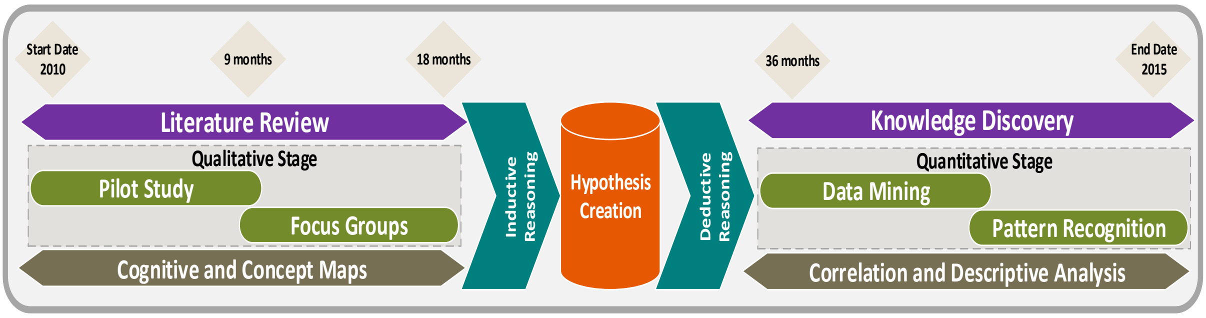


Figure 11: Research Timeline

As illustrated in Figure 11, the second stage of the study was explanatory to demonstrate 'why' it is happening and using deductive reasoning achieve a clear demonstration and a validation of the hypothesis and was made of two research techniques: pattern recognition and data mining. Findings from both stages were used to evaluate the electronic communication patterns within construction projects.

Table 3 illustrates the Research steps and outcomes in more detail.

Table 3: Research Steps and Outcomes

Research Area	Data Collection	Analysis	Objectives	Knowledge
Communication Protocols, Practices & Media (qualitative)	Pilot Study (Interviews)	Interpreting results using Cognitive and Concept Mapping	Conceptual map of current communication practices	Variables and their importance on affecting communication patterns
Communication and BIM (qualitative)	Focus Groups	Interpreting results	Confirmation of developed Conceptual maps and level of BIM adoption	Professionals' understanding of BIM and their level of BIM adoption within the industry
Communication (quantitative)	Data Mining	Statistical Analysis	Relationship between project characteristics and level of electronic communication	Better understanding of document management system schema
Communication (qualitative)	Pattern Recognition	Correlation and Descriptive Analysis	Correlation between project characteristics and variables	Categorisation of projects based on their activities

4.2.1 Research Methodology

After a considerable amount of critical reviewing of research methodologies and analysing the importance of paradigms and philosophies in social research, the purpose of this research involves gaining knowledge, contributing to existing knowledge and discovering solutions to real-world problems.

This social research aligns with social constructivist thinking which is based on the epistemology paradigm and adopts a mixed method strategy; qualitative and quantitative approach driven. A mixed method approach is practical as it allows the researcher to use all methods possible (using both numbers and words) to address the research problem (Creswell and Plano Clark, 2007). It also provides a more comprehensive picture by providing in-depth knowledge of participants' perspectives and experiences as well as noting patterns of behaviour and generalisation (Creswell and Plano Clark, 2007). The strategy is a Sequential Exploratory, which involves the first stage of the study to be qualitative data collection and analysis, followed by a second stage of quantitative data collection and analysis that builds on the results of the first stage (Creswell, 2009). In such a strategy the weight is often placed on the initial stage (qualitative stage in this case) and data will be mixed when presenting the results and discussions.

In social sciences, knowledge and meaning of social phenomena is constructed over time and re-constructed through experience. Therefore, for this research a constructivist view has been adopted as the researcher engages in the process improving the prior knowledge through new experiences as well as creating new knowledge based on research results and findings (Bryman,2008). In constructivism (interpretivism), the researcher is involved in the process of knowledge creation and since all knowledge is relative to the researcher, participants' points of view, perceptions and experiences will be interpreted by the researcher in the context of the research.

Although a pragmatic view has been identified as a philosophical underpinning for mixed method studies (Mingers and Gill, 1997; Creswell and Plano Clark, 2007; Bryman, 2012), a constructivist approach has been selected for this research. The constructivist view believes that there cannot be just one single truth. Especially within a social context, truth or meaning comes into existence as a result of our engagement with human beings, social phenomena and realities in the world and therefore meanings are constructed in our minds based on our experiences and interactions with the world (Crotty, 1998). Based on this recognition of knowledge it is clear that individuals undertaking the same research construct meanings in different ways and this research is no exception. The constructivist view was adopted at the start of this research and even though the aim of the research changed the philosophical underpinning remained the same. Although pragmatism gives the researcher the freedom of choice of methods and techniques but it does not focus on an individual's interactions and the specific context in which people work in. In addition, because the intention of this research was to apply HCI theories, i.e. CSCW and CMC concepts, the researcher recognised that her own background and theoretical knowledge in computer sciences would have a significant impact on understanding the problem, interpreting the data and proposing solutions.

"Highly organised research is guaranteed to produce nothing new."
— Frank Herbert

A qualitative approach was chosen for the first stage of the research (i.e. Pilot Study and Focus Groups) merely because the research problem was 'immature' and 'broad' due to lack of previous research and the need to explore the problem in more detail and describes the phenomena in greater depth (Creswell, 2009). For this reason, the approach to first stage of this study is largely inductive and exploratory that addresses group and personal communication patterns and identifies techniques in light of Computer Mediated Communication (CMC) and Computer Supported Collaborative Work (CSCW) to discover principles and facts. Findings are presented using a Descriptive Narrative method and the use of rich pictures.

A quantitative approach then follows the first stage to test the hypothesis derived from the first stage results and its ultimate acceptance or rejection and to generalise the outcome in accordance with the communication framework (maturity model) proposed. An aim of this research is to reveal users' behaviour and activity patterns using statistical analysis to conceptualise the real world processes in an attempt to make predictions on how these activities or processes would operate in a BIM environment (Field, 2000). For this reason, the approach to the second stage of the research is largely deductive and explanatory and uses Ethnographic methods as a form of analysis to document human behaviour and patterns within the context in which it occurs (Pickard, 2013). The main focus of ethnographic studies is to evaluate groups' interactions and behaviours to generate an understanding of cultural phenomena within that group via qualitative research methods including observations (Pickard, 2013). However, to serve the purpose of this study, an ethnography approach has been adopted in a different way. Even though the aim of the second stage of this research is to evaluate project participants' interaction patterns but the evaluation process is not undertaken using qualitative methods. Instead, interactions between participants is studied through a data set and their interactions will be quantified and analysed using statistical analysis. Statistics and statistical analysis consists of a number of procedures, including data collection, data processing via classification and tabulation, comparison, analysis and interpretation to draw a logical conclusion based on the processed data similar approach to Patel's (2012).

The second part of the research has been identified as quantitative; however, it is also partially qualitative in nature and it is only the analysis that is using quantitative methods, i.e. Cross-tabulation, Correlation Coefficient and quantitative tools, including SQL, Excel and SPSS. Cross tabulation is used as a quantitative method for finding the links between variables and also any correlations between them. SQL, Excel and SPSS are used as a tool to produce graphs, tables and reports to demonstrate any correlation or links between variables to the reader. Tashakkori and Teddlie (2003) have highlighted the importance of integrating qualitative and quantitative data. They believe data integration is the final stage where both data sets are integrated into one coherent set. Integration in this study occurred after analysis of the quantitative data (second stage) and for interpreting the data. Interpretation of the results of the second stage is demonstrated using Descriptive Analysis which is again an interpretation of the results with regards to the research problem. According to Patel (2012, p.5) descriptive analysis provides "*numerical description of events under study according to existing situation through reduction of available data*".

In this research, the proposed framework is developed based on the results from both stages. The second stage of data analysis is quantitative using SQL database management and producing reports using Excel and SPSS. However, the description of events and prediction of impacts of BIM on communication patterns and inducting a generalisation as to where the industry would be placed within that framework are all based on previous knowledge and results from the qualitative stage are explained and discussed qualitatively.

This is one of the many reasons why the pragmatism approach has not been adopted for this research, which is linked with mixed method strategy. Because although utilising a collection of qualitative and quantitative methods are classified as mixed methods it is a different case in this study. The purpose of this strategy is to initially explore a phenomena and a problem area and then use quantitative data analysis to assist the interpretation and validation of the results of the qualitative stage.

4.2.2 Research Methods

Research methods according to Pickard (2013, p. 99) are "*bounded system created by the researcher to engage in empirical investigation, the overall approach to the investigation*". Simply, they are processes or tools used for collecting and analysing data.

The findings reported in this thesis are based on the following combined research techniques:

- A Pilot Study to; a) investigate the existing communication practices, b) instability in projects' communication systems, c) identify the channels and ways in which project participants communicate, d) distinguish which communication protocols are more important to project groups and e) address project and personal communication patterns to make sense of individuals' experiences. This is to create new knowledge and reflect on derived understanding, what is already known and what is not known will be questioned, explored and assessed using active techniques in a social context. Using mapping techniques develop a hypothetical/theoretical model that can be measured.
- Two Focus Groups to approach more professionals in industry to confirm the preliminary research data and also to identify project participants' expectation and perceptions of BIM and existing BIM applications.
- Data Mining to analyse a large set of data (extracted from a project extranet firm) and through SQL database management to extract any trends, patterns of behaviour and meaning of the data.

- Descriptive Analysis to a) predict the impacts BIM may have on electronic communication practices of construction projects and b) induct a generalisation with regards to where construction projects within the UK would be placed within the developed communication framework, using Correlation analysis on the outcome of the data mining stage to establish a correlation between variables, project characteristics and the level of electronic communication.

4.3 Data Collection Design

4.3.1 First stage – Qualitative

This part of the research is inductive as it is moving from an explicit observation to generalisation and hypothesis creation. This is a vital part of data collection that results in creating a conceptual map of existing electronic communication practices.

4.3.1.1 Pilot Study

The pilot Study was designed to gather information about the current working and communication practices, critical evaluation of construction dynamics and to get a general view of the nature of the problems based on an individual's experiences at project and organisational level. The pilot study was conducted for the first run of data collection and prior to the focus groups to identify:

- The role participants play as an individual within their organisation and the projects they are involved
- The role their organisation plays in projects
- The ways in which they communication and exchange information
- Types of electronic communication systems they use to communicate
- The project's quality assurance processes, contractual agreements and procurement methods
- The project's communication strategy and policy
- Their understanding of electronic communication systems, mainly e-mail and how they are utilised

Due to the qualitative nature of the study and to achieve a consistent data set, a small sample was selected among project consultants and engineers to be interviewed. Individual practitioners in the sample were chosen because they:

- Had many years of experience in industry
- Came from different backgrounds with different specialities

- Were completely familiar with the construction culture and environment
- Came from a mixture of small-medium and medium-large sized organisations
- Had minimum level of using electronic communication systems
- Had extensive e-mail experience

Ten interviews were conducted with above characteristics and primary data was collected using semi-structured face-to-face interviews, to go deep into descriptions of events and capture implicit knowledge. In the analysis stage, all interviews were tape-recorded and listened to once finished. Interviews were transcribed accurately and accordingly afterwards. The transcriptions were used for further in-depth data analysis using Semantic Text Analysis tools. Nvivo 8 and word clouds (section 5.2) were used as the text analysis tool to look for commonly used words and to count the frequency usage of words to show the number of occurrences in each textual data.

This method of analysis which is based on Template Analysis phenomena helped the researcher classify significant patterns and produce themes identified in the textual data (King, 2004). E-mail, Communication, Information, People and Project are the codes that emerged from the interviews.

Some of these codes were identified prior to the study but they were modified and added by progressing through the transcripts (King, 2004). Cognitive mapping technique was used for every single transcription to represent individuals' knowledge about the four main categories. Figure 12 illustrates one of the many cognitive maps produced.as an example. For rest of the maps please refer to Appendix A.

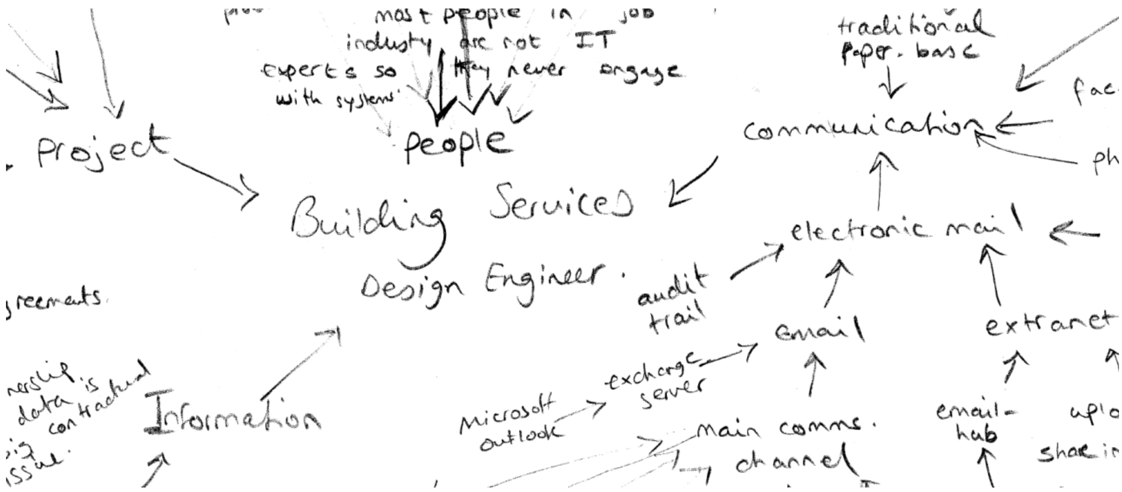


Figure 12: Example of a Cognitive Map

Cognitive mapping is "*a means of modelling subjective reasoning based on the psychology of personal construct theory*" (Mingers and Gill, 1997, p.61). It is primarily designed for structuring the data as well as capturing the research subjects rather than the researcher's perception of the ideas and their relationships. (Montello, 2002). The links are proactive and identify some sort of relationships. These codes were used as the central concepts on the map. Maps were drawn based on interviewees' statements linking to the appropriate concept.

After completion, all the maps were compared to discover relationships and variables that affect the electronic communication systems. After completion of the pilot study researcher had a better understanding of construction processes and communication patterns. This led to more critical thinking with regards to the problem area and how the focus groups may be designed to get the full benefit and understanding from professionals with regards to their understanding of BIM, their expectations of BIM and their communications habits and how that might change with BIM.

4.3.1.2 Focus Groups

Two Focus groups were undertaken to further investigate the problems with e-mail and other existing collaboration systems as well as identifying industry's understanding of BIM, how it is getting implemented, professionals' expectation and perceptions of BIM and existing BIM applications. This was done to note if the true concept of BIM has become reality and also if there is a potential of integrating BIM and E-mail to create new communication mechanisms which are spatially aware and sympathetic to the working practices of construction. A focus group is a small group of people that are brought together to discuss in a group setting their opinions, beliefs and perceptions on a specific subject area (Pickard, 2007; Bryman, 2012; Pickard, 2013).

Two focus groups were conducted with leading firms in the construction industry that have partially incorporated or are planning to incorporate BIM in their working practices; one is a main contractor (a medium sized organisation) and one is an international product manufacturing company. Each focus group gathered between 6-12 representatives (different roles) from their diverse sectors. The duration of each focus group was around 90 minutes where each individual helped identify what/who/how and why they communicate; identify industry needs in terms of BIM implementation and key issues on BIM, expectations and perception of BIM-based collaboration platform across different disciplines. The purpose of the discussions was introduced at the beginning and discussions were moderated by Northumbria BIM Academy research team, who are currently working on a bigger project with these companies.

Focus groups were observed and data was tape recorded as well as collected in post-it-notes and field notes. Recorded data was then listed to a number of times and only comments and portions of the data that were related to this research study were transcribed. Condensed transcription was produced and it was served as the basis for further analysis. For analysis, transcribed text with additional post-it-notes and field notes obtained during the focus groups were linked to the three themes of technology, process and people, previously discussed at pilot study in order to make sense of data gathered in both stages in Chapter 7. Data analysis based on this coding scheme allowed visualising various issues and concerns discussed by participants.

4.3.2 Second Stage – Quantitative

This part of the research is deductive as it is moving from an explicit hypothesis to generalisation and prediction of future possibilities. This is also a vital part of data collection that results in justification and validation of the hypothesis as well as developing the conceptual framework of communication and predicting where the industry will be placed on this framework.

4.3.2.1 Introduction of the Database

The purpose of this stage is to critically evaluate electronic communication patterns and people's activities by practically measuring data from ViewPoint's (former 4Project) database reporting system to identify and classify variables and project characteristics that have an impact on electronic communication level. This part of the research aims to present data in the most objective and proven context and the unit of analysis is going to be project based.

4Projects is an established Software as a Service (SaaS) company and a Microsoft Gold Partner and one of the biggest in the UK who provides a platform for Construction projects to manage and communicate their information. Their platform was initially developed to serve the Construction projects and it consists of two systems: an old version (2G) and an updated version (3G). 2G system is table based (relational database) for different items and 3G system, shown in Figure 13, is container based (hierarchy database with nested tables) that manages a massive hierarchy. The purpose of upgrading to a hierarchy system is to be able to zone off and view the system at the highest level (so called the ROOF) to observe the state of all activities. The database hierarchy is important to understand as it is related to how queries should be written to extract the right data for further analysis.

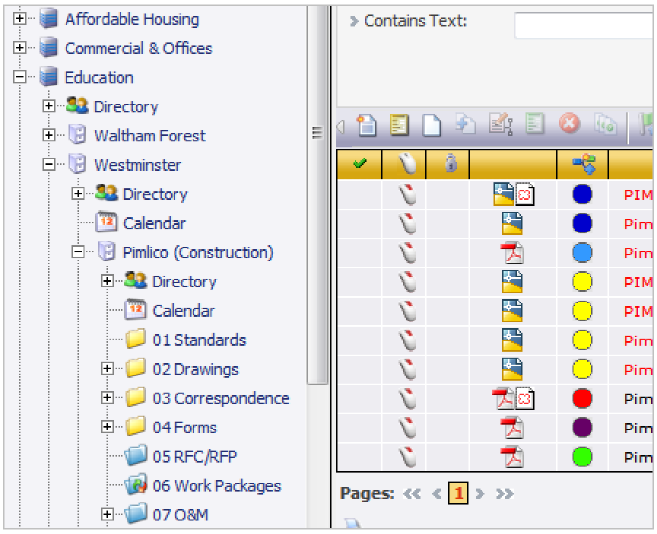


Figure 13: SaaS Company 3G system

The fundamental functionality of the 3G system is that it builds a very low level breakdown. For every project on the system there is a container that hosts different types of information regarding that project, such as document folder, discussion folder, task folder and etc. Even though 3G has more elements, the report produced from both systems is similar. For the purpose of this research, a subset of the database (from their reporting system) with anonymised ID’s and name hashes are used. The SaaS Company also have a separate system called Salesforce that manages their clients’ information.

According to Succar (2009) while it is important to establish metrics and benchmarks to measure BIM performance, "*it is equally important for these metrics to be consistently accurate and adaptable to different industry sectors and organisational sizes".* For that reason, a large sample of projects has been chosen over a period of 5 years to cover both design and construction stages. This enables the researcher to generalise the findings for different industry sectors.

Various statistical analysis methods were considered and studied;

- Interactive Visual Analysis – a method to extract knowledge from large sets of data utilising computational data with the rational and thinking abilities of humans.
- Time Series Analysis – a collection of data points and observations over a certain period of time.
- Neural Networks – a machine learning technique to model complex situations.
- Descriptive Analysis – statistical procedures (average, mean, standard deviation and correlation) to provide brief summaries about certain features and observations about a data set.
- Inferential Statistics - statistical procedures (linear regression and correlation coefficient) to provide predictions about a data sample or population.

Based on the nature of this research study, the method of approach for this stage is a combined Descriptive Analysis and Inferential Statistics. Descriptive Analysis techniques allow the data set to be analysed to identify patterns and discover new knowledge then using Inferential Statistics induct a generalisation to a bigger population.

Since the data-set has a complex hierarchy with a very large amount of anonymised raw-data, a Data Mining process has been undertaken prior to statistical analysis to filter the data and find useful information for further analysis.

4.3.2.2 Knowledge Discovery in Database Process

Knowledge Discovery in Database (KDD) refers to the iterative process (a sequence of steps) for evaluation and interpretation of patterns from a data set to extract useful data from it (Zaiane, 1999; Marban*et al*., 2009). Knowledge Discovery in Database is done by utilising Data Mining methods to identify patterns according to the objectives, in this case in accordance with research aim and hypothesis. Data mining is the core step of the KDD process for excavating large data sets to find valuable information, hidden patterns, analytical information and development of meanings of the data based on the analysis of it (Zaiane, 1999; Marban*et al*., 2009). Data mining methods are used for various types of databases including hierarchical databases. Data mining tools are usually computer based which confirm or contradict a hypothesis and allow for a prediction of behaviours and probable future trends based on past values (Zaiane, 1999).

The challenge with KDD processes is that there are no widely accepted standards, methods and procedures for data miners with different expertise and from different backgrounds to utilise. There are several KDD models and methodologies developed by researchers (Table 4); Fayyad *et al.* (1996), Cabena*et al.* (1998), Annand and Buchner (1998), Cios*et al.* (2000) and CRISP-DM developed in late 1990's by a large group of European companies.

Table 4: comparison of KDD processes taken from (Kurgan and Musilek, 2006)

Model	Fayyad et al.	Anand and Buchner	Cabena et al.	CRISP-DM	Cios et al.
Origin	Academia	Academia	Industry	Industry	Academic/Industry
Number of steps	9	8	5	6	6
Steps	1. Developing and understanding the application of domain 2. Creating a target data set 3. Data cleaning and pre-processing 4. Data reduction and projection 5. Choosing the data mining task 6. Choosing the data mining algorithm 7. Data mining 8. Interpreting mined patterns 9. Consolidating discovered knowledge	1. Human resource identification 2. Problem specification 3. Data prospecting 4. Domain knowledge elicitation 5. Methodology identification 6. Data pre-processing 7. Pattern discovery 8. Knowledge post-processing	1. Business objective determination 2. Data preparation 3. Data mining 4. Domain knowledge elicitation 5. Assimilation of knowledge	1. Business understanding 2. Data understanding 3. Data preparation 4. Modelling 5. Evaluation 6. Deployment	1. Understanding of the problem domain 2. Understanding of the data 3. Preparation of the data 4. Data mining 5. Evaluation of discovered knowledge 6. Use of the discovered knowledge

Fayyad *et al.* (nine-step model) and Anand and Buchner (eight-step model) were amongst the first in academia to develop KDD models. Industrial experts such as Cabena *et al*. (five step model) and CRISP-DM (six step model) followed academia to develop leading industrial models. Successful development of academia and industrial KDD models led into development of Hybrid models which include some aspects of both worlds. Such a model was developed by Cios *et al.* (six-step model) based on CRISP-DM and it was alerted it to suit the academic research and provide a more research-oriented description of the steps (Marban *et al*., 2009).

Based on the comparison between KDD models and for the purpose of this research Cios *et al*.'s model has been selected to perform data mining and statistical analysis on the data set. Cios *et al.*'s model is drawn from both academia and industry which is mainly used for software development and includes explicit feedback loops. The processes involved in Cios *et al*. Model are, also shown in Figure 14:

1. Understanding of the problem domain – Initial step involved identifying the goal of KDD process which in this case was to confirm/contradict the research hypothesis as well as predicting future trends. Research hypothesis was developed based on the results from the first stage of the research and translated into data mining goals.
2. Understanding of the data – This step included identifying the schema and receiving the data set. Also time spent during this stage was to:
    - Installation of appropriate version of Structured Query Language (SQL) Server Management and ensuring it is securely connected to Northumbria University's server. At the same time attending online SQL courses (e-learning modules) to study and acquire the right skills to utilise SQL and perform the right queries
    - Installation of appropriate version of Statistical Package for the Social Sciences (SPSS) and ensuring it is compatible with Excel to be able to import and export data
    - Understanding the relationships between tables (1 to 1 and 1 to many relationships). As explained earlier in the chapter, it is important to gain a comprehensive understanding of the database system and the schema behind it to be able to perform the right queries to obtain the right data

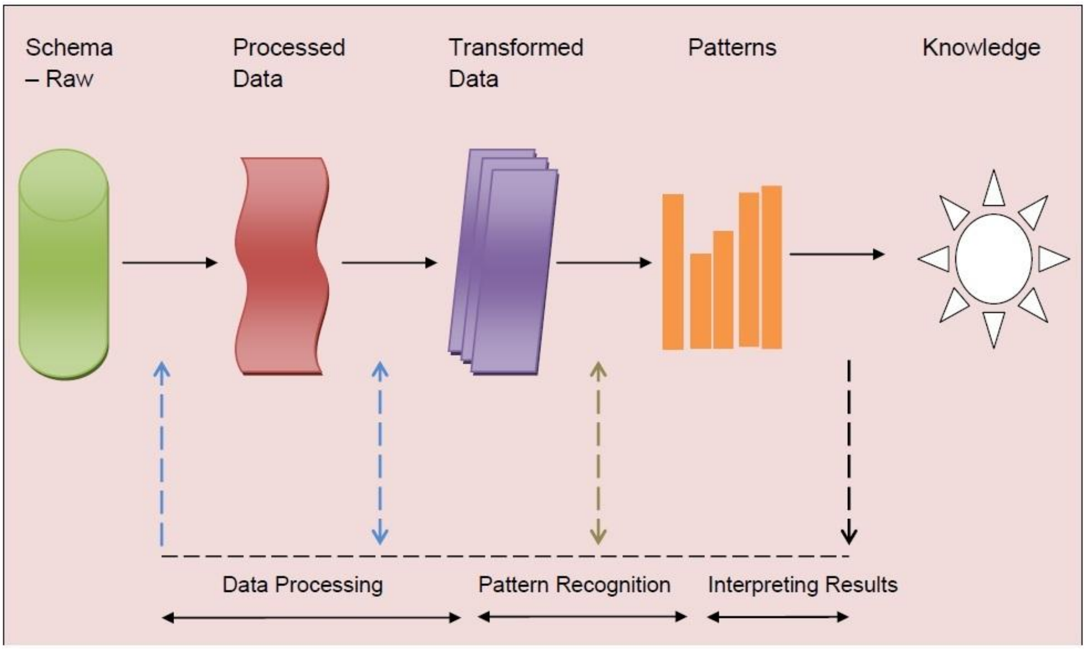


Figure 14: Knowledge Discovery Process

3. Preparation of the data – This step is concerned with making sense of raw data and discovers first insights into the data. Usually raw data is inconsistent and may contain errors. Therefore this step involves running queries to identify data quality problems and remove any noise or missing values. The preparation or pre-processing of the data is used to prepare raw data for further processing.
4. Data mining – During this stage knowledge is derived from pre-processed data. Using background knowledge and data mining goals established in the 1st step and using tools such as Excel and SPSS various graphs, charts and correlation analysis emerged.
5. Evaluation of discovered knowledge – This step is concerned with understanding the results and graphs to see whether derived knowledge is useful and contributes to the goal of the research. During this stage useful results and graphs will be retained and the rest of the results will be revised to identify whether they can be improved or used in some other forms.
6. Use of the discovered knowledge – The final step is to decide how to present the new knowledge and how to make sense of it with regards to the aims and objectives of the research.

Each step, alongside the results, is explored further in Chapter 6.

4.4 Reliability and Validity

It is crucial that every effort has been made in order to have a sound research methodology for data collection, analysis and interpretation (Creswell and Plano Clark, 2007). According to Creswell and Plano Clark (2007) an important factor of a good research is clear explanation on validity and reliability of data and results. During data collection and data analysis of this research study both reliability and validity are considered.

Validity, sometimes referred to as credibility, is about the strengths of a research study. Validation of findings and research study in general occurs throughout the process of research (Creswell, 2009). Qualitative validity is a set of procedures that a research must take in their study to determine the accuracy of findings. To ensure the validity and accuracy of findings of the pilot study interviews, the researcher conducted a follow-up discussion with a number of the participants to discuss the themes and categories emerged from the data and asked for any further comments. Contradictory evidence (discussions and notes) from the focus groups to theoretical frameworks has been presented to reflect a more realistic view of what is currently happening industry wise, to ensure the validity of the focus groups.

Reflectivity is a core element of qualitative research (Creswell, 2009) and it includes clarification of the bias researcher brings in to the study. Even though in analysis stage of both the pilot study and the focus groups an 'objective' approach was adopted in order to analyse the data and have the most accurate results but, researcher has clearly highlighted and explained interpretations and discussions of the findings is influenced by Computer Sciences background, i.e. HCI theories.

An important element in ensuring the accuracy and validity of results of data analysis during knowledge discovery process was the data mining approach (Imielinski and Mannila, 1996). There are various factors that must be considered when choosing and applying data mining methods; the outcome of the KDD process and how to change that to a data mining goal, the broad analysis techniques, tools to utilise for knowledge discovery and the background knowledge of the researcher which all have impacts on what method to use. These elements were identified by the researcher and as a result more time was spent during understanding the data and data preparation steps to ensure database structure (schema), data itself and any noise or missing values within the data set had been identified and dealt with to be able to produce more accurate results. Also to deal with the problem of scalability of the data mining when processing a huge data set, it was ensured that suitable analysis tools including SQL server management and SPSS were utilised to avoid any data sampling.

To ensure validity within a mixed method context, all data gathered from both stages (qualitative and quantitative) have been used to draw an explicit and precise conclusion. Also to minimise the threats to validity of sequential design, the researcher used a small sample size for the pilot study and focus groups and a large sample for quantitative data analysis.

As well as validity, it is important to consider the reliability of the research study. Reliability is about the researcher's approach being consistent across different occasions so that the answers are consistent (Creswell, 2009). It has been suggested by Yin (2003) to document as many of the procedures of a research study as possible when undertaking qualitative research. During this research study the researcher ensured data collected and analysed are reliable. Some reliability procedures undertaken during both qualitative and quantitative stages of this research were as follow:

- Interviews/transcripts have been mapped out as a way to reflect on and visualise the thoughts and ideas gathered.
- Once interviews were transcribed and mapped, a copy was shared with the participants for validation and to ensure their point of view had been captured and mapped correctly.
- The emergent findings were discussed explicitly during internal PhD symposiums as well as internal seminars and conferences to gather other researchers' thoughts and inputs.
- Different SQL queries were run with the same purpose to ensure results obtained are accurate.
- Engagement with Statisticians and Computer Scientists to ensure methodology utilised for query writing and statistical analysis was correct.
- Continues engagement with supervisors to ensure rigour in the findings.

It can be argued that there are different strategies and methods of assessment of validity and reliability of a research study but not all are appropriate in interpretive and exploratory studies. In exploratory studies, it is extremely difficult to assess and demonstrate reliability as it can be assessed in different means and not necessarily using the existing terms.

4.5 Ethical Considerations

All research with human participants requires careful attention to participants' rights. It is therefore the researcher's responsibility to acknowledge any ethical issues or risks in the study and follow the required ethical codes and guidelines to ensure participants' identities are protected at all times (Creswell, 2009; Pickard, 2007). Creswell (2009) believe that ethical issues apply to all methods of research and at different stages. Therefore, it is important to be aware of them and address them as they arise. According to Bryman (2012) there are four main ethical principles in social research:

1. Harm to participants
2. Lack of informed consent
3. Invasion of privacy
4. Deception

The issue of harm has been addressed by maintaining the confidentiality of identities and records, both during data coding and any publications by using pseudonyms (Bryman, 2012).

And the issue of deception, invasion of privacy and informed consent has been addressed by using a formal consent form from Northumbria University's standards and codes of practice in which research aims and objectives were explained clearly in both writing and verbally.

In developing invitation letters for participants to take part in the pilot study, the researcher ensured the central intent of the research is clearly described (Creswell, 2009). Also, during both the pilot study and focus groups the researcher ensured the purpose of the research was clearly explained and that participants understood it fully. Formal consent forms that were prepared for these interviews contained the name and researcher's supervisor details, in case participants required further clarification or felt the need to discuss any concerns regarding the research and how it was conducted. All forms were read and signed by participants before engaging in the research. Because some discussions during the interview covered participants' work experience and their company's work practices and some policy and issues related to their work environment, participants were guaranteed total confidentiality and anonymity with regards to their responses. All participants understood what they were agreeing to, felt comfortable with the research purpose and gave informed consent (Pickard, 2013).

In the analysis stage of the pilot study interviews and focus groups, names were disassociated from responses during cognitive mapping and coding of data to protect their identities (Creswell, 2009). In the thesis writing stage, there is no referral to names and participants will be totally anonymised if any statements are to be published. Also a Non-Disclosure Agreement was signed at the start of the data mining process (user profiling and understanding users' behaviour in the second stage of the research) between Northumbria

University and the SaaS company (please see Appendix B) to ensure any new implicit knowledge about groups or users will be fully anonymised before any publications to prevent their identities.

The researcher takes full responsibility and ownership of research data. All interviews were transcribed by the researcher. Cognitive and concept maps were drawn on big pieces of paper; these maps have been transformed into an electronic format (via scanning) and the paper copies are kept in a safe area. The only person who has access to all research data is the researcher. All of the recorded tapes and written data will be kept for the duration of the research and destroyed right after in accordance with Northumbria University's requirements.

CHAPTER 5 – STAGE 1 RESULTS

This chapter demonstrates the main findings from the qualitative stage of the research. The results in this section are based on the following combined research techniques; a pilot study and two focus groups. The pilot study was conducted using semi-structured interviews with professionals from the industry. The interviews were tape-recorded and transcribed for further in-depth analysis using text analysis tools, including Nvivo and word clouds, to get a general view of the nature of the problem based on individuals' experiences at project and organisational level. Once codes and patterns were identified, cognitive mapping technique was used to structure the raw data (i.e. transcripts) and demonstrate the interviewees' ideas and relationships about the research subject.

Following from the pilot study, two focus groups were piloted to identify industry's understanding of BIM. The focus groups were also tape-recorded and transcribed for analysis based on the patterns and themes that emerged from the pilot study.

5.1 Pilot Study

A pilot study was designed to gather information about current working and communication practices, critical evaluation of construction dynamics and to get a general view of the nature of the problems based on individuals' experiences at project and organisational level. The pilot study was conducted with the following professional roles as outlined in Table 5.

Table 5: Participants' Details

Participant	Role	Firm	Purpose	Size
1	Project Manager	Client	Requirements Setting	Medium-Large
2	Design Manager	Architectural	Design	Small-Medium
3	Principal Architect	Architectural	Design	Small-Medium
4	Architectural Technologist	Research & Development	Standards Settings	Medium-Large
5	Design Manager	Main Contractor	Design & Build	Medium-Large
6	Planner	Main Contractor	Construction	Medium-Large
7	Quantity Surveyor	Main Contractor	Design & Build	Medium-Large
8	Building Services Engineer	Main Contractor	Design & Build	Medium-Large

The aim of the pilot study was to investigate the existing communication practices within construction projects to; a) identify communication protocols, processes and media and establish the relative importance to project stakeholders and b) capture individuals' experiences and consider these in relation to communication practices. As explained in section 4.3.1.1, a number of interviews were undertaken as part of the pilot study to gain a qualitative view based on the experience of the participants, however, these were not intended to be utilised and presented as quantifiable results. Thus, they had an unstructured format to allow participants to freely discuss and move to other problem areas that they felt were most relevant to the focus of the interview, which may have not been anticipated by the researcher.

5.1.1 Communication Protocols, Processes and Media

Results from the Pilot Study are categorised as below;

5.1.1.1 Communication Protocols

During the Pilot Study, it was observed that there are a variety of communication protocols, which involve people and processes, and depending on the size of organisation the protocols become more formal and restricted. These protocols can be categorised as below:

<u>E-mail related protocols</u>

It was observed that e-mail escalation policies existed within all the organisations and with regards to e-mail authorisation; almost all firms allowed all staff to send and receive emails unless they were a temporary employee and or had not been given an email address. Table 6 demonstrates the findings with regards to e-mail authorisation.

Table 6: E-mail Authorisation in different firms

Role	Firm Size	Authority to send e-mail
Design Manager	Small-Medium	Yes
Principal Architect	Small-Medium	Yes
Design Manager	Medium-Large	Yes
Planner	Medium-Large	Yes
Quantity Surveyor	Medium-Large	Yes
Project Manager	Medium-Large	If they have an e-mail address
Building Services Engineer	Medium-Large	No - if temporary
Architectural Technologist	Medium-Large	No - if temporary

The remaining findings with regards to e-mail protocols can be broken down into three main categories with regards to organisations' size:

Small – Medium size Firms

In all small-medium sized firms there is no audit trail to track e-mail. Employees rely heavily on searching e-mail based on their subject line. Being copied into e-mail has become a huge problem as employees receive more than they need. There are no rules or policies around copying people in and it is up to employees' professional judgement as to whether they feel others need to be copied into e-mail. Also important issues, discussions via telephone and notes on site were mostly recorded by e-mail. In some cases issues that were raised and captured via e-mail were tracked via read receipts, high importance flags and a response time. In cases where an important issue had been raised it was normally followed up via a phone call. Job-specific e-mail were transferred into a folder where all other e-mail relating to that job were stored.

Medium – Large size Firms

In medium-to-large size firms 34% of the respondents' e-mail and electronic document management systems were managed by their internal IT team and 66% had their E-mail system and their electronic document management systems externally hosted. Although these firms are bigger in size and are expected to have policies around e-mail archival, 16% of respondents said that there was no strict policy for e-mail archival within their organisation and e-mails were expected to be treated as tasks. In addition, the external companies that were hosting their electronic document management system had ownership of their extranet site. 16% believed that their firm's e-mail archival policy hugely depended on their procurement strategy. In relation to replying to e-mail the procedure within these larger organisations is still to "reply to all" rather than to be selective about who to "copy in". In cases there was doubt over who needed to see an email, the tendency was to broaden the circulation. There was no prioritisation of e-mail; every e-mail seem to be classed as important regardless of the importance status flag attached by the sender.

<u>People and Technology related protocols</u>

In both small firms and larger organisations, the project leaders, whether designers or contractors, were allocated responsibility for managing information flow. On bigger projects where an extranet had been utilised there was always the role of a document controller to ensure information was distributed correctly.

In general, small firms still use "cabinet" style filing systems, i.e. windows folder structure, on a centralised server for storing project information. This typically leads to the entire management of information flow/workflow being executed manually. Although the workflow is a manual process there is little version control in place internally; version control is only used when documents need to be sent out externally. Certain small practices have started using web-based services for sharing correspondence, drawings and documents so that the whole project team can have access to information. However, there is no automation or workflow management behind this type of systems and the process of notifying others of an update or change is manual. For instance, person uploading a new piece of information is responsible for notifying relevant project members (via e-mail) that a new piece of information, i.e. drawing, now requires their attention and that this supersedes previous work. There are no specific processes/procedures in place for tracking/following-up on an issue raised, a change request or a Request For Information (RFI). Certain file formats are contractually accepted; DXF, DWG and PDF are the fixed file formats that are acceptable contractually in small firms.

5.1.1.2 Communication Processes

Regardless of the size of practice two main categories of communication process can be observed, formal and informal.

<u>Informal Communication Processes</u>

Informal Communication Processes are internal processes within each organisation's "work in progress" (WIP) environment. Although all firms have some sort of internal document management systems in place (whether electronic, paper-based, on a network or web-based) information, in any type or format, needs to be reviewed and approved before being issued externally to the wider project team. Hence, participants tend to use tools such as e-mail, phone or team meetings to share un-controlled and un-approved information before publishing on the extranet for comprehensive use.

<u>Formal Communication Processes</u>

Formal Communication Processes are both internal and external processes in which project participants share/exchange information. E-mail, when used as a formal communication mechanism has the same legal implications as a letter and has contractual implications. Extranets as a project shared area the most formal form of communication where only approved documents and drawings have been shared.

5.1.1.3 Communication Media

The results from the Pilot Study highlighted 5 key communication media; E-mail, post, phone, File Transfer Protocol (FTP) links and Electronic Document Management Systems (EDMS) or Extranets.

Small-Medium Sized Firms

Although the industry is moving towards a more digitised and data-driven environment, the use of telephones (to discuss and resolve urgent issues), posting CDs, USBs or formal letters is still quite common within smaller firms. Because a lot of contractors still require hard copies, paper-drawings are still being utilised and issued via fax or scanned to an electronic format for archival purposes. In most cases it is partly paper and partly electronic communication and there are no specific roles and responsibilities around managing the communication strategy and electronic communication systems.

The use of e-mail and FTP links is very popular for transferring/exchanging electronic documentation. E-mail has become the main channel for distributing documentary information, supporting collaboration and personal and business interactions between individuals. E-mail has become the fastest, easiest and most efficient way to communicate and update other stakeholders; thus it has become a central part of the communication workflow. Even though e-mail is now the main means of information and document exchange, still there are many limitations for file transfer. File sizes can become too large and attachments can clog the inbox. Due to large file sizes, information from the sender must be abbreviated and summarised to a level that facilitates the transmission, i.e. files are split, compressed and sent in two or three e-mail. Therefore, some information must be reconstructed from the e-mail message, hence the greater the level of summarisation, the greater the potential for error during reconstruction. This will result in time and effort being wasted. Some files that are too big in size will be transferred via FTP links or web-based tools such as Drop-Box.

The average volume of incoming e-mail is from 40 to 150 e-mail per day per person. This has made e-mail management a task in its own right, with time allocated to do it. Peer-to-peer communication predominates and ease use of e-mail has let people send e-mail as many times as they want. Sending an e-mail is cost free for the sender, in terms of time and effort, however for the receiver to be receiving too many e-mail per day has a cost implication in terms of time and effort. All e-mail responses demand some input and some thought which will need consideration time. So e-mail are quite costly to the receiver and tend to reduce the efficiency and quality of the output of the team.

The main reason that small-medium sized firms (particularly smaller firms) do not invest in electronic document management systems is because of the cost of installation and maintenance. Having a reliable network capable of handling a folder structure, with everyone in the office having access to this network, is fit for their purpose. It was also noted that in small firms everyone knows each other quite well and there us similar amount of trust between all the employees.

Medium – Large sized Firms

The use of e-mail is common within medium-large sized firms, especially for informal processes. Even the larger organisations complain about e-mail sizes being an issue. E-mail also serves as a notification tool which has been integrated with extranets for project shared area. Professionals can either get daily notifications or get immediate notifications. In larger organisations the use of extranets is more prevalent for document management. This is mainly because they deal with larger projects and sit between the sub-contractors and the client therefore they would need a controlled environment. However, there is no standard approach to communication on these extranets despite project size and cost. In larger organisations the use of mobile technology is also popular but yet the use of telephone is also common. Prioritisation of use of media within larger organisations depends on the importance of the issue raised. The importance of issues is usually left to the professional judgement of project participants.

5.1.2 Participants' experiences

Interviews were conducted around the experiences that respondents had within their organisations regarding communication. This section provides anonymised examples of typical situations encountered by the respondents.

5.1.2.1 Communication Protocols

Participants' communication experiences have also been categorised as e-mail-related and people- and technology-related protocols. The sub-sections below include quotes from participants. Transcriptions for some of the interviews can also be found in Appendix E.

<u>E-mail Related Protocols</u>

Respondent A – "everybody has authority to send emails; we've never had a problem where someone sends something inappropriate. I think everybody is pretty mature about this and if they've got a technical query or they think that there might be a bigger issue they would talk to either the next grade up, a senior person or they might even talk to a partner because we are only relatively small practice so there is usually a partner around to ask".

Respondent B – "In our company some managers say; do not check your email till 4pm. If it is something urgent they will ring you and if it needs recording then email it".

Respondent C – "Some people treat email as a task. They come in turn their laptop on check their emails only, turn their laptop off go back on site and come back again after a few hours to check them again".

Respondent D – "all face-face discussions or conversations via phone have to be recorded via e-mail. Particularly if the issue has contractual implications then we have to ensure it is recorded and then as the lead consultant we would instruct the contractor to make a change. It is very important for us as the lead consultants (and architects) to do this because not only are we responsible for delivering the project and the performance of all consultants, we are also responsible for delivering the project on time and on budget, this way we take a view of the whole picture and by controlling things we make a judgement whether a change is absolutely necessary".

Respondent E – "E-mail is used a lot within our firm therefore there is an IT role just responsible for management and maintenance of e-mail systems. Updates will be sent around the office via e-mail over night or on a weekend. Transfer of e-mail to specific folders is supposed to happen on a weekly basis but it is an individual's responsibility to ensure to transfer them across. Once a project is complete all e-mail and correspondence relating that specific job gets moved to our archive server".

<u>People and Technology related Protocols</u>

Respondent A – "Practice policy for everyone is to list all job related issues in terms of priority but we don't probably police it like that".

Respondent B – "Some of the web-based document management systems (extranets) acted as a repository only, therefore project participants had to set their preferences to be notified if something had changed on the site which of course if you are not an IT expert, which a massive people within the industry aren't, never engage with it and are never happy with it. Hence, project participants end up asking for information being sent through e-mail and this breaks the chain".

Respondent C – "The industry is full of 50+ category of people who have not used computers all their career and for them now to change the whole paradigm of how they work, it is very difficult. Therefore, some of them still want hard copies with engineer's check signature on it".

Respondent D – “I think it is the culture. It is the culture of the construction industry. Sadly, there is not so much in Britain, although it exists in other countries you go to a meeting where each person goes to it bring a lawyer with them. Everyone is looking out to protect their interests within the project”.

Respondent E – “Technology and bandwidth supporting these extranets are not advanced enough to support the exchange of information models”.

5.1.2.2 Communication Processes

Informal Communication Processes

Respondent A – “I have had experience using a few different extranets; but you end up sending information through emails, you know the stuff that are kind of draft or informal and then sort of officially issue things using the extranets if you like”.

Respondent B – “Only because there are written procedures in place, it does not mean that is the best way of doing things. I kind of did what worked. Often it was an improvement of what they were trying to get you to do. These procedures are important because if people do not understand what they are supposed to be doing it helps them to put them on the right track. But if you have innovation and better way of doing things, often the company would say you cannot do that and you have to do it this way”.

Respondent C - “Interestingly we architects have 2 ways of approaching the data; one is to keep all the print and copies of documents and the files , the second one is to use the appropriate management system, in our case it is a system designed by architects so that when you create a document whether it is a letter or a drawing or an email, it creates a unique code and it puts it in a particular place in the project database so that everybody has enough access to it and everyone knows where it is and it is on your server , when it is on our server, we run backups of our server every evening and I take one home the next day, so we always got the latest version of whole data base”.

Formal Communication Processes

Respondent A – “As lead consultants we take overall responsibility and Quality Assurance (QA) plays a vital part for our firm, hence we need to ensure we have ultimate control over change or we will be held responsible for our information being changed without our knowledge and it may be used on site. As a result, we are very restrict when it comes to change procedures and we require our contractors to talk directly to us and this has to be done formally and by writing (usually via e-mail)”.

Respondent B – "On site, there is an issue sheet which lists all the drawings, specification and other type of information that has been created or communicated by us. This issue sheet has a date of when it was issues, revision number and at the bottom there is a distribution list, which lists all the people who should receive a copy. At any point in time consultants or the contractor can take a look at the list and find out what the latest version is for a particular document and when it was issued. Once this sheet has been issued tick boxes are ticked to keep for us as a record".

Respondent C –"The document controller guy has the role of information flow. He controls the documents on extranet sites whether internally or coming from outside and directs it to the right person. On bigger projects we might have a number of document controllers. Distribution lists and packages are based on Work Breakdown Structure or their procurement method".

Respondent D –"There were certain projects that their communication strategies were to only communication through extranets and ignore any e-mail sent in relation with these projects. Some of these extranets were just a repository and did not have notification alerts included in their system. When an engineer or designer who logs on in the morning they log-on in to their internal systems and they have a number of projects to look at. This meant they had to specifically make the effort to on to project specifics sites/systems to check any new/outstanding tasks/actions and/or look for information. Therefore there could be a break if not logged-on for 2-3 days and an important issues could be easily missed. Therefore, I firmly believe there is a close tie between how projects communicate to how they are procured. Because the procurement root sets where the decision making power lies and therefore how the roots of communication speaks to it".

Respondent E – "Lack of consistent standards for file naming has resulted in uncategorised documents which creates problems when searching for files and results in waste in time and effort".

5.1.2.3 Communication Media

Respondent A – "Because the person who is building the building tends to still work on a piece of paper, pin it on the wall and then have it there when working, paper is still important so we still print on A1 size drawings, pretty much everything we do, and we will print on A4 joins to match all of the text that is associated with that , specification, a description what this table is made of and how its put together whether in the building, or be on an A4 piece of paper, or an A1 drawing, so they are fundamentals".

Respondent B – “at the moment we do not manage e-mail that well and we would simply search for that topic in our emails so if it was about ordering tables we take an order of tables and will see but to be fair it is quite rare that we need go backwards, we are too busy going forwards”.

Respondent C – “although we had extranet sites, what we used to often do was to just open an email with outlook and distribute it via email. So even though we had this storage electronic document management system for drawing we still distributed via email”.

Respondent D – “As a medium sized practice we use email extensively. We do not actually have an extranet site but everybody has access to the server out of hours from home. So we have a FTP link that enables them to do that. We have never really needed an extranet as such”.

Respondent E – “if you get copied in once something has been uploaded so you will get copied in when someone comments on it or approve it and etc. So you can end up with a number of things to clear which is not really for an action. The names tend to be on the system. It could be a lack of knowledge of how to use the system properly. There are trainings available; there are a lot of people to train on large projects”.

Respondent F – “Problem with extranets is that it does not really prioritise these issues. They just had them like; you have 3 new documents that you have not looked at”.

Respondent G – “the problem with the email is always this assumption once you have sent it, the other person has read understood it correctly and also being able to action it. The issue that I have with it is that in legal terms, as a quantity surveyor, contract legal statement those kind of stuff, claims, constructions issues where legal and contracts get involved, a lot of people do not realise an email carries the same sort of legal way as writing a letter, they all thing that a letter is a formal thing like a big warning shot whereas an email is not. I think what people regard email as an informal method of communication with formal influence”.

Respondent H – “a lots of our customers did not trust email and there was a problem as well that these and these forms or communications had to be signed and so people tended to print them out and sign them”.

Respondent J – “I used to handle a minimum of 150 emails a days. All of them would be demanding some input, some thought and the issue that then creates from a design perspective is, it does not give any time to consider. Most people thought well I have sent the email, therefore I have done my job therefore I expect a response in 5 minutes. Some other people use email system as a get out of jail, because if I can send an email that says yes or no I have done it".

5.2 Summary

E-mail has become the main communication channel in both small and large firms and for both formal and informal communication processes. As a result, management of e-mail, i.e. search, retrieval and archival, has become an issue as e-mail is used not only for communication but also for managing tasks and personal activities. The culture of using e-mail also appear to be a concern as professionals within the industry are expected to rely on their professional judgement to; act on an e-mail, include the right parties in e-mail, avoid sending unnecessary mails and consider that e-mail have the same legal status as the written letter. Users are overloaded with e-mail with average of 80 e-mail per day per person. The integration of e-mail and extranets (for workflow automation) has made things worse as some users receive notifications on a daily basis and these e-mail all require some sort of input requiring time spent. Extranets are the second main communication channel for sharing formal communication, i.e. approved documentation. Extranets have workflows configured to push the flow of information. In most cases (larger projects) there is a need for a document controller to distribute the information between project parties.

NVivo 8 (Table 7) and word clouds (Figure 15) were used as the text analysis tool to look for commonly used words and to count the frequency usage of words to show the number of occurrences in each textual data (i.e. each interview script).

Figure 15: Word Cloud image

E-mail, Communication, Information, People and Project are the codes that emerged from the interviews.

Table 7: Word count and occurrence

Word count	Occurrences	Percentage
E-mail	133	0.72
People	122	0.49
Project	121	0.46
Information	102	0.41
Communication	39	0.15

Cognitive mapping technique was used to represent individuals' knowledge about the five main categories (for remainder of the maps see Appendix A)

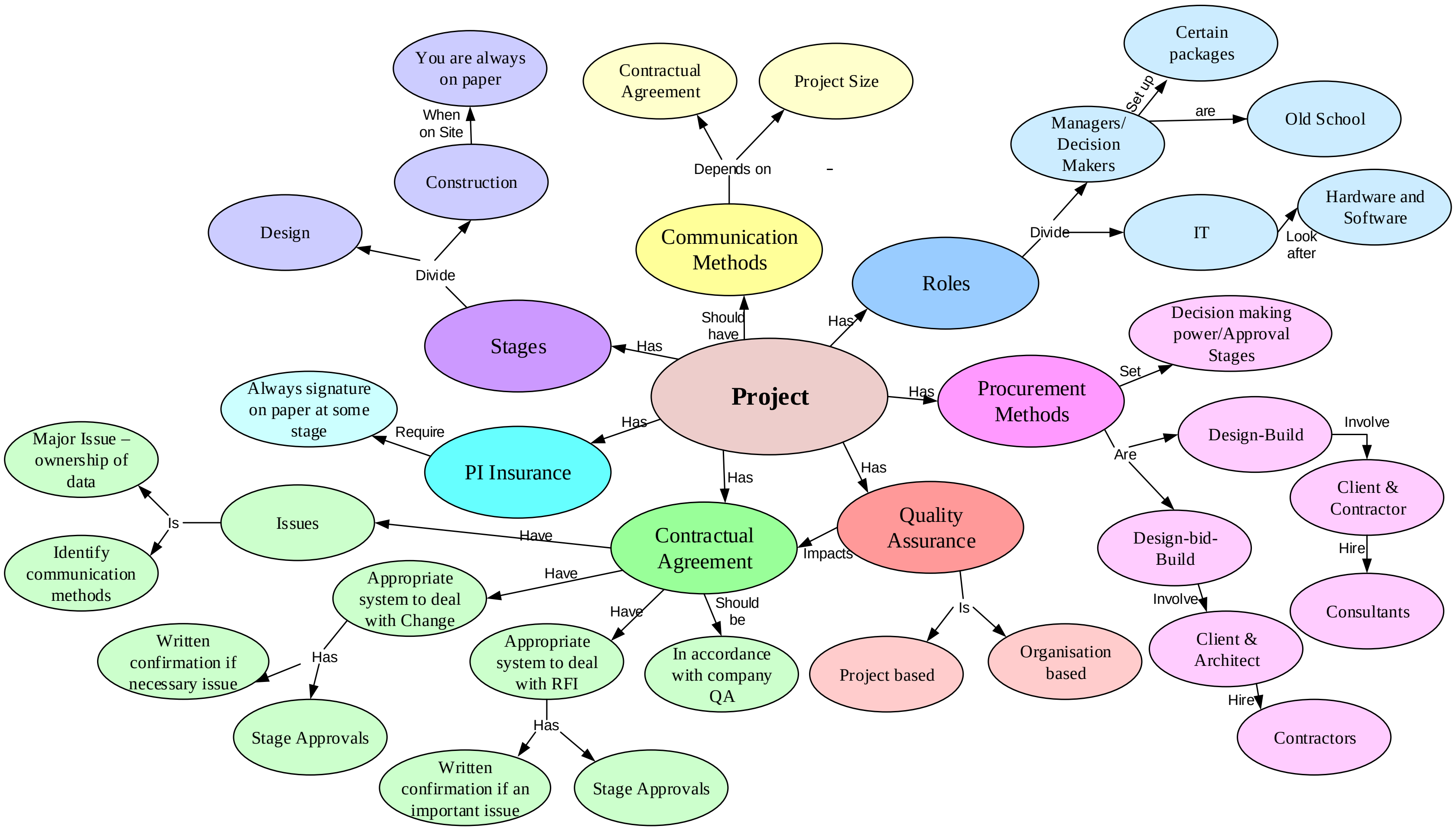


Figure 16: Example Project Cognitive Map

After completion, all the maps (example illustrated in Figure 16) were compared to discover relationships and variables that affect the electronic communication systems. The main variables that emerged from the maps which had direct impact on electronic communication systems and methods were as follow:

- Construction Culture
- People Behaviour
- Information Management
- Roles and Responsibility
- Company Quality Assurance (QA)
- Traditional ways of working
- Procurement Methods
- Contractual Agreements

These variables are discussed further in Chapter 7.

5.3 Focus Groups

Two focus groups were undertaken to identify industry's understanding of BIM, professionals' expectations of BIM and existing BIM applications and their perceptions on the existing communication processes. The two focus groups were conducted with leading firms that have partially incorporated or are planning to incorporate BIM in their working practices; one is a main contractor and one is a manufacturing company. Each focus group gathered between 10 -15 representatives (Table 8) from diverse sectors within the organisation. Some of the representatives' roles are as follow:

Table 8: Focus Groups Representatives' Roles

Organisation	No. of Participants	Roles	Data Collection Technique
Main Contractor	8	BIM Engineers BIM Modeller BIM Strategy Manager Senior Design Manager Senior Project Manager	Brainstorming Observation
Manufacturer	12	Planning manager Business development manager Technical Manager Research & Development Project Manager	H-form with post its

They helped identify how they communicate to clarify the results from the pilot study stage, identify industry needs around implementation of BIM, expectations and perception of BIM-based collaboration platforms across different disciplines. The focus groups were moderated by the Northumbria University BIM Academy research team, who are currently working on a bigger project with these companies.

5.3.1 Pilot Study results verification

Observations and findings relating to verification of pilot study results are categorised into three main themes as the pilot study's focus; communication protocols, processes and media.

- Communication Protocols – Participants suggested that in most cases communication protocols and collaborative frameworks were not discussed and agreed upon early enough in a project life-cycle and there is not enough awareness as to what these protocols are within the project team. E-mail is often utilised for exchanging project information, typically in a PDF or Drawing form as an attachment, with no prior agreement on project level in relation to meta-data and what should be captured or how it should be laid-out/archived. Not all project participants archive these e-mail on project shared area. The ones who do may save them differently (using different naming convention) as there has been no agreement in advance which makes it very difficult, time consuming and in some cases impossible for others to search and retrieve. Participants strongly believe that replacing PDFs and Drawings as immutable files is never going to happen as they are contractually accepted outputs. This is mainly due to clients' requirements, finding it easier to maintain and manage documents.

- Communication Processes - results from the focus groups also identified internal processes for communicating project information, these included file naming conventions, data exchange protocols and file identifier metadata. This requires a significant manual processing and rework at approval stages. In addition, there was little evidence of the use of a Common Data Environment (CDE) as recommended by BS1192:2007. A lack of communication strategy and a collaborative framework was apparent from the responses of the participants.
- Communication Media - Focus groups revealed that existing communication processes rely heavily on e-mail and that project information, once approved, is shared via an extranet. Participants also confirmed that the integration of e-mail and extranets has caused e-mail/information overload with lots of automated e-mail coming through to communicate updates or changes made on the extranet which causes distraction. Although the general feeling was that e-mail isn't the right tool for communicating project information (in particular model files and large drawing

files) yet participants still use it as they feel it is the fastest and easiest tool to use, especially if still in work in progress stage of the CDE.

Table 9 demonstrates examples of participants' examples on BIM from both the pilot study and the focus groups.

Table 9: Examples of participants' statements on BIM from Pilot Study and Focus Groups

Pilot Study	Focus Group 1	Focus Group 2
We want to make sure our authorities and responsibilities are fully recorded and managed	Collaboration technology not all freely available to everyone	People can build what is in BIM using a different system without knowing how actually goes together.
Information issuing is changing with BIM	Bandwidth and technology is not advanced enough to support the communication	With BIM Our Products can be matched with other products in industry
Better collaboration with BIM	Different tools to create building models	We don't think BIM can take Certification Requirement in
We tried to keep the same system and QA procedures and it was really difficult to keep track of it	Not enough standards, property sets	It gives a lot of people a little information, without giving the background on how to use that information
Traditional ways of working don't work too well in the BIM environment	How do we validate a model? Can it be done using IFC's?	You might put something on BIM and leave your phone or e-mail address for correction

5.3.2 Participants' expectations and perceptions of BIM

The key themes around BIM that emerged from the focus groups were, as expected, focused around people, process and technology. People-related results are focused around issues concerning; roles and responsibilities, lack of general awareness, lack of training and change readiness. Process-related results are focused around inadequacies in current processes and what is expected to change to suit the implementation of BIM. Technology-related results are focused around limitations of current systems and expectations of future BIM platforms.

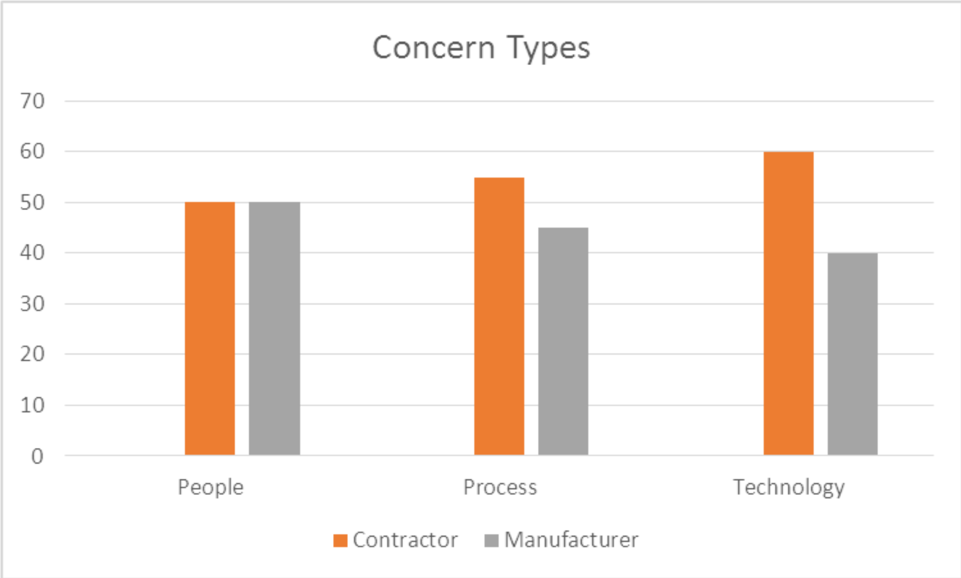


Figure 17: Focus Groups Concern Types

People related concerns seem to be equally important for both the contractor and the manufacturer (Figure 17). However, it seems that technology is more of a concern to the contractor than the manufacturer and the manufacturer's focus is more around processes. Findings are explained in more detail in following section.

5.3.2.1 People

The focus group findings suggest that there is a general unfamiliarity with the concept of BIM and that perception, understanding and expectations of BIM differ across disciplines. For example, to designers BIM means 3D modelling and utilisation and visualisation of data for better design management processes whereas BIM for major contractors is about project and information management and for clients it is mainly around a consistent set of standards and processes to capture and communicate all information requirements consistently. Both focus groups agreed that there has been a lot of attention paid to the 3D modelling and technology aspects of BIM within the industry and therefore lack of clarity on implementation of BIM at the more strategic levels.

There are also major concerns in relation to intellectual property, liabilities, ownership and responsibilities around information issue using BIM. Both groups strongly believe that new roles and responsibilities should emerge to manage exchange of information models, especially on more complex projects. In their experience information models are regularly updated and information is constantly modified, therefore it is vital to appoint roles in advance to check, approve and sign off these changes. Although there was a general agreement in both groups that information within models should be owned by a specific role, both groups were having difficulties seeing how this may work. For example, with documents it is easy to manage the approval process whereas with digital information within models, there is dynamic information defined by classes/schema of entities and components, rather than information within static documents. So does this mean the project lead is responsible for all the changes and/or updates? Or would it be the person authoring the tools responsible for specific parts/components of the model which they are working on? Would the roles and responsibilities be transferred to the client once the project is complete and handed-over? Or would the designer or contractor still remain responsible for the information model? These and other questions raised as a result of this discussion will be addressed in Chapter 7.

5.3.2.2 Process

Findings from the focus groups suggest that implementation and adoption of a single information model for interdisciplinary collaboration requires an understanding of the collaboration and information requirements and project specific contingencies. There are concerns around the creation, use and management of information in an interdisciplinary environment due to poor systems and process integration. Drawings within construction projects are still contractually required as deliverables and therefore professionals use these information models to extract drawings to produce the output which is used for decision making: the information model itself is mainly utilised for clash detection and conveying information within discipline-specific teams. Both groups firmly believe in the need for a new design/construct process (i.e. Integrated Project Control/Delivery (IPD)) to move away from the traditional management processes around documents and drawings. This is mainly because an information model can be used to produce many drawings (i.e. different views of the model) at any given time and any changes to the model will result in updates to all the drawings. For this reason, new processes such as IPD are required to put in place control and validation processes that are more suited for models than drawings.

5.3.2.3 Technology

It was noted by the focus groups that there are different software tools/packages to create, use and manage information models. These modelling tools are exclusively designed for multi-disciplinary design teams and are disconnected from one another, with different file formats, object libraries, schemas and model representations. This has resulted in interoperability and file size issues. Interoperability is the ability to share information between different models without the need to extract models as files. This has also caused issues relating to model validation and change management; both groups recommended a mechanism for identifying a role responsible for making any changes and/or holding back any changes in the working model. Otherwise these changes would not be captured in automatically generated drawings (which is the way to exchange information currently) and this would result in coordination errors. Interoperability and bandwidth limitations are one of the many reasons why the industry is not mature enough to utilise BIM servers.

5.4 Summary

Observations and findings from the focus groups are categorised into the following three key areas:

People – There is certainly a lack of general knowledge, initiative and training and an unwillingness to change the current ways of fragmented working. There is a need for more push from the Government to provide the right materials as well as training courses and accreditations to upskill professionals. The training courses should support cultural and behavioural change.

Process – There is certainly a need for a more collaborative frameworks and more integrated processes. There needs to be standards in place to define the validation and verification processes as well as roles and responsibilities around it for ensuring the content of information model is governed and reliable.

Technology – Interoperability seems to be the biggest issue, together with bandwidth limitations for transferring model files. There were concerns around the quality of IFC files and there was general consensus that there should be a standard classification system for structuring model files for consistency and ease of model file exchange.

CHAPTER 6 – STAGE 2 RESULTS

This chapter demonstrates the main findings from the quantitative stage of the research. The purpose of this stage is to critically evaluate electronic communication patterns and people's activities by practically measuring data to identify and classify variables and project characteristics that have an impact on electronic communication level. The results in this section are based on data mining and statistical analysis techniques.

Based on the nature of this research study, the method of approach for this stage is a combined descriptive analysis and inferential statistics. Descriptive Analysis techniques allow for the data set to be analysed to identify patterns and discover new knowledge then using inferential statistics induct a generalisation to a bigger population.

Since the data-set has a complex hierarchy with a very large amount of anonymised raw-data, a data mining process has been undertaken prior to statistical analysis to filter the data and find useful information for further analysis.

6.1 Hypothesis Testing

A hypothesis was developed in section 3.6 based on the literature and after carefully reviewing the results from both the pilot study and the focus groups. The hypothesis is that the implementation of 'Lonely BIM' and the use of traditional working practices will increase document correspondence within construction projects

This stage of the research is to test the hypothesis, via the Knowledge Discovery Process as explained section 4.3.2.2 on a data-set extracted from an extranet server which contains various examples of project information with the intention of searching for significant patterns to make sense of the data-set.

6.1.1 Understanding of the problem domain

The purpose of this step is to determine the end result of the whole Knowledge Discovery Process (KDP) and translate the research hypothesis into data mining goals. The required output of the whole KDP is to justify the research hypothesis by revealing significant relationships between the following characteristics:

- Information exchange volume (cost)
- Document creation (cost and quality)
- Project duration (time)
- Project phase (time and cost)

- User (cost and quality)

These five characteristics are recognised, based on the pilot study and focus groups results, to assist in identifying patterns of behaviour.

6.1.2 Understanding of the data

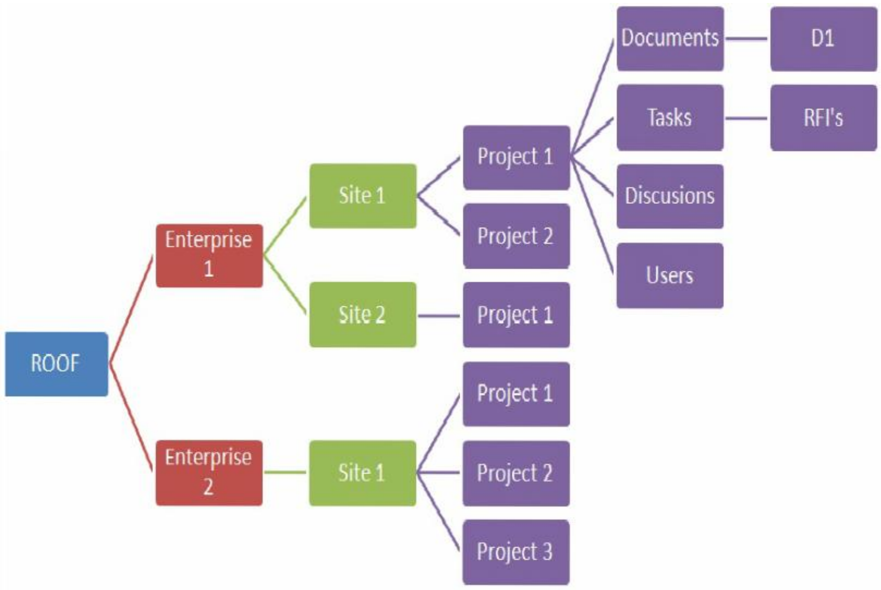


Figure 18 : Database Hierarchy

It is crucial to understand the data-set, the schema behind it and the relationships between the tables before simplifying and removing unwanted data for further analysis. As explained in section 4.3.2.1, the database is a subset of a bigger data-set extracted from a Software-as-a-Service (SaS) or an extranet server which has specifically been designed for Construction projects. The data-set was extracted using SQL Server 2008 and it is a hierarchal database with nested tables which has a highest level called the ‘ROOF’. The ‘ROOF’, as shown in Figure 18 then breaks down into different Organisations (so-called ‘Enterprises’) which then further breaks down to different business areas/departments (so-called ‘Sites’).

Each Site then could have a number of Projects and each Project could have a number of Sub-Projects running underneath. All Project information, i.e. documents, tasks, discussions, etc. are expressed in a container format. Essentially, the database has a parent-child or 1-to-many relationship.

For better understanding the meaning behind the dataset a data dictionary (Table 10) was also created:

Table 10: Data Dictionary

Column	**Datatype**	**Length**	**Nulls**	**PK**	**FK**
Name	nvarchar	20	No		
ProjectTypeID	smallint		No	Yes	ProjectType.ProjectTypeID
ProjectID	uniqueidentifier		No	Yes	Project.ProjectID
DateCreated	datetime		No		
CreatedbyID	uniqueidentifier		No		Project.CreatedByID
ParentID	uniqueidentifier		Yes		
UserID	uniqueidentifier		No	Yes	
JobTitle	nvarchar	50	No		
OrganisationName	nvarchar	50	No		
OrganisationID	uniqueidentifier		No		
DateCreated	datetime		No		User.DateCreated
FolderTypeID	smallint		No	Yes	FolderType.FolderTypeID
FolderID	uniqueidentifier		No	Yes	Folder.FolderID
DateCreated	datetime		No		
CreatedbyID	uniqueidentifier		No		Folder.CreatedByID
ParentID	uniqueidentifier		Yes		
FolderTypeID	smallint		No		
HasEmailBox	bit		No		
DocumentTypeID	smallint		No	Yes	DocumentType.DocumentTypeID
DocumentID	uniqueidentifier		No	Yes	Document.DocumentID
RevisionName	nvarchar	20	No		
RevisionStatus	nvarchar	50	No		
DateCreated	datetime		No		
CreatedbyID	uniqueidentifier		No		Document.CreatedByID
IsLatestRevision	bit		No		
WorkflowStatus	nvarchar	50	No		
FileTypesCsv	varchar	50	No		
HasAttachments	bit		No		
HasMarkups	bit		No		
DateRequired	datetime		No		
PercentComplete	int		No		
LinkID	uniqueidentifier		No	Yes	
SourceDocumentID	uniqueidentifier		No		
TargetDocumentID	uniqueidentifier		No		
TransactionID	uniqueidentifier		No	Yes	
CreatedbyID	uniqueidentifier		No		

The database dictionary has been created to demonstrate the associated tables using Primary and Foreign key to understand the relationships between the tables. This would help with query writing.

6.1.3 Preparation of the data

During this stage the data-set was investigated to find valid data and discard noise and outliers. Since the database had a large data-set, it was necessary to look for data that is relevant to this research project which can then be analysed further. The characteristics that were considered to filter the data were as follow:

- Project type – there were a lot of projects on Enterprise and Site level, i.e. more complex, more expensive and longer (duration wise) programmes. Only projects that were on Project level were considered for the purpose of this research and rest were discarded.
- Projects less than one year in duration – there were many sub projects with duration less than a year. Less than 1 year projects may not have enough activities to demonstrate a good indication of patterns of behaviour to be able to draw a conclusion from it.
- Active projects – there were also many incomplete projects which were discarded. The aim of this research is to explore the whole projects life-cycle, therefore only finished projects were retained.
- Test projects/profiles – there were also a lot of test data, test user profiles and null values which had been created as the source of the data-set to test the system and its performance.

Filtered data, based on the above characteristics was then in an appropriate format to be aggregated into new tables which were then utilised for data mining utilising further and more advanced SQL queries.

6.1.4 Data mining and Evaluation of discovered knowledge

6.1.4.1 Data Mining – step 1

In this step various statistical methods were applied in order to extract data patterns from pre-processed data. Data patterns, results and graphs were then evaluated to derive useful knowledge that contributes to the goal of the research. During this stage useful results and graphs were retained and the rest of the results were revised to identify whether they can be improved or used in some other forms.

Some of the first steps taken in this stage were to understand the basics and gain a comprehensive overview of the data-set, including:

Total number of pieces of information that have been uploaded onto or downloaded from the system, across all projects per month (as illustrated in Figure 19) to understand the trend of information exchange volume over time.

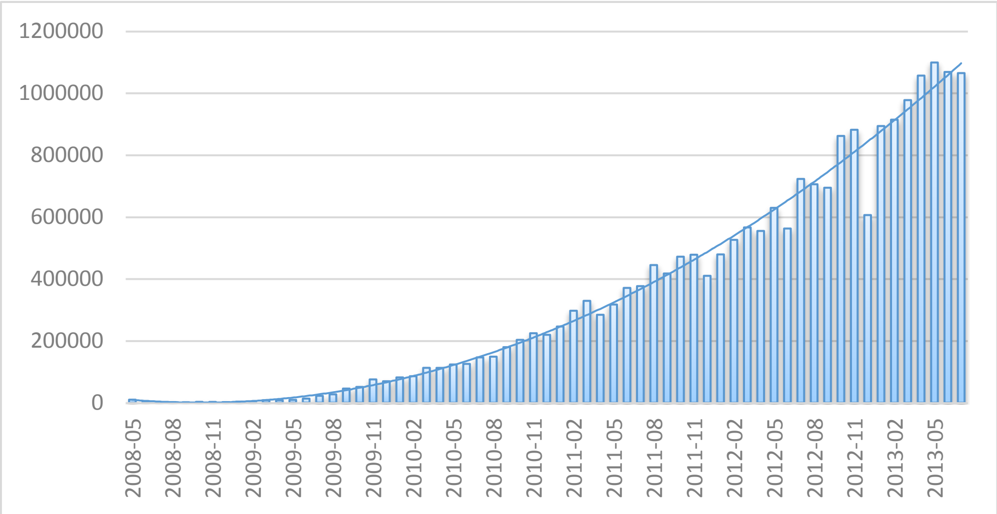


Figure 19: Total number of Uploads and Downloads per Month

Total number of projects created per month (as illustrated in Figure 20) to compare with the information exchange volume, to ensure the increase in information exchange volume is not due to increase in use of the system (i.e. more projects) and it is due to more information being uploaded and downloaded from the system.

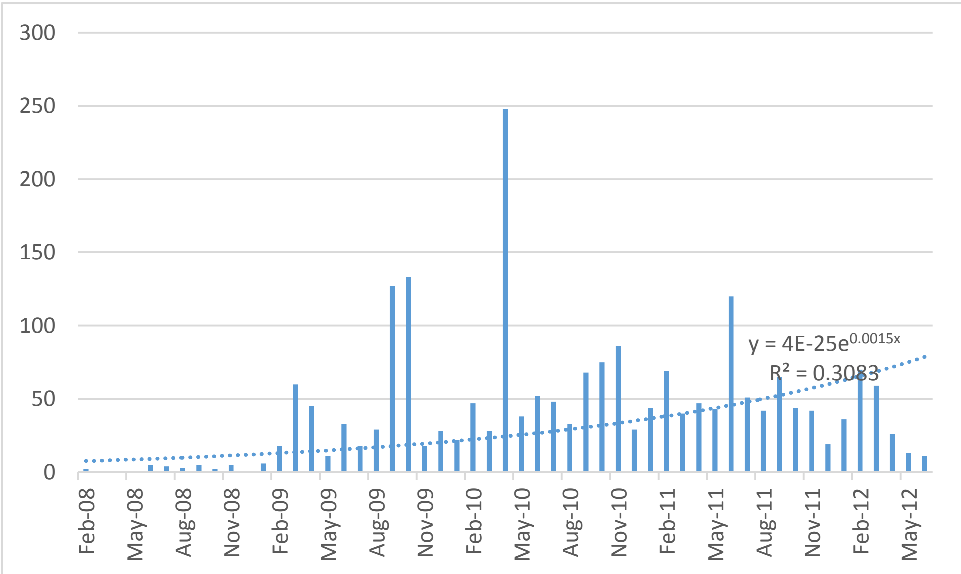


Figure 20: Number of projects created

As explained earlier in this chapter, the system holds all project information in containers. The next step was to investigate the number of information uploads and information downloads per container type over time, illustrated in Figure 21.

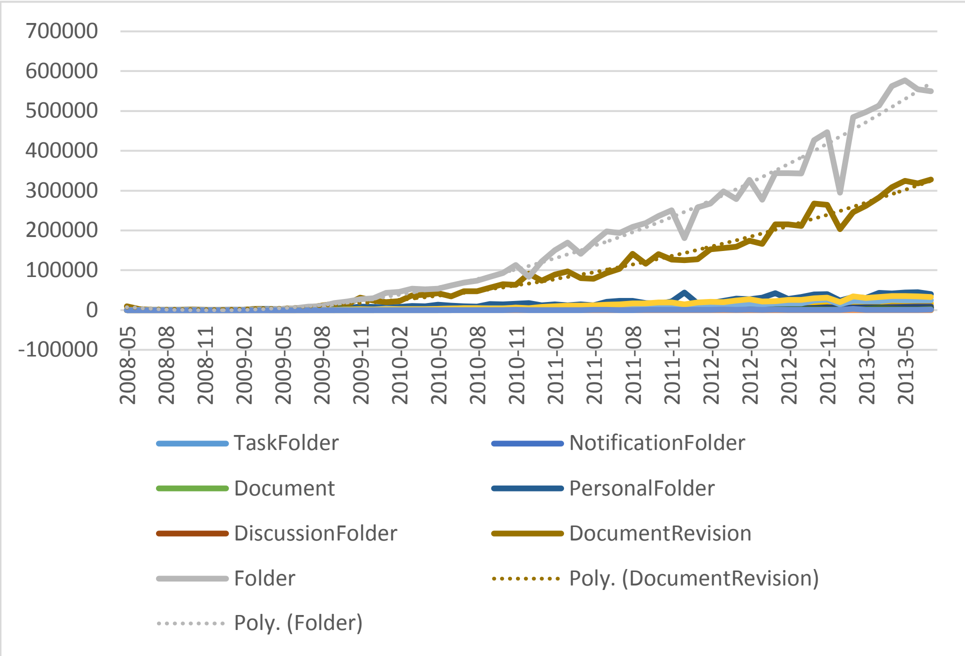


Figure 21: Uploads/Downloads Per Container Type

This was in order to understand which containers had the most information uploaded and downloaded. The containers were then explored further to find any BIM related files, as illustrated in Figure 21.

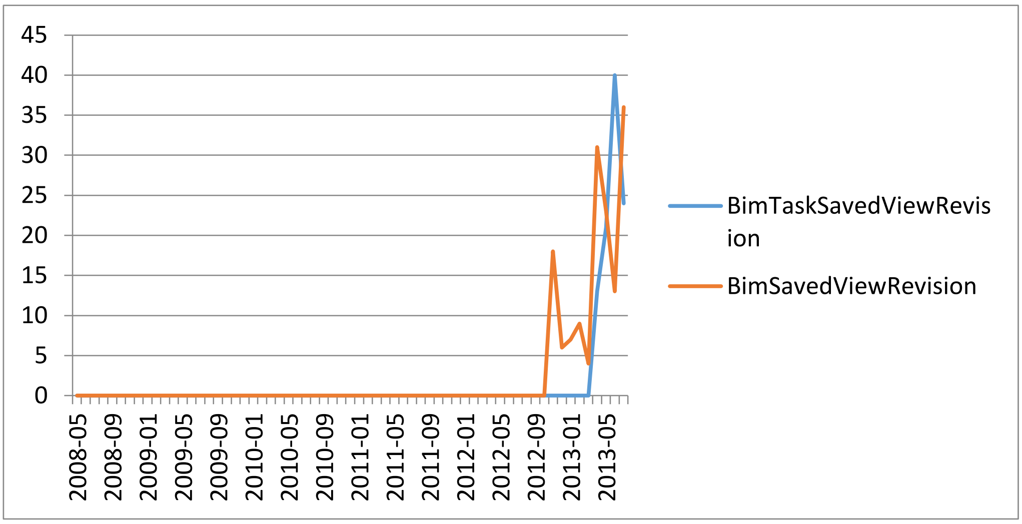


Figure 21: Number of BIM Files

The next level down from projects is the Folders, which were explored to find out how many folders were created each month (illustrated in Figure 22).

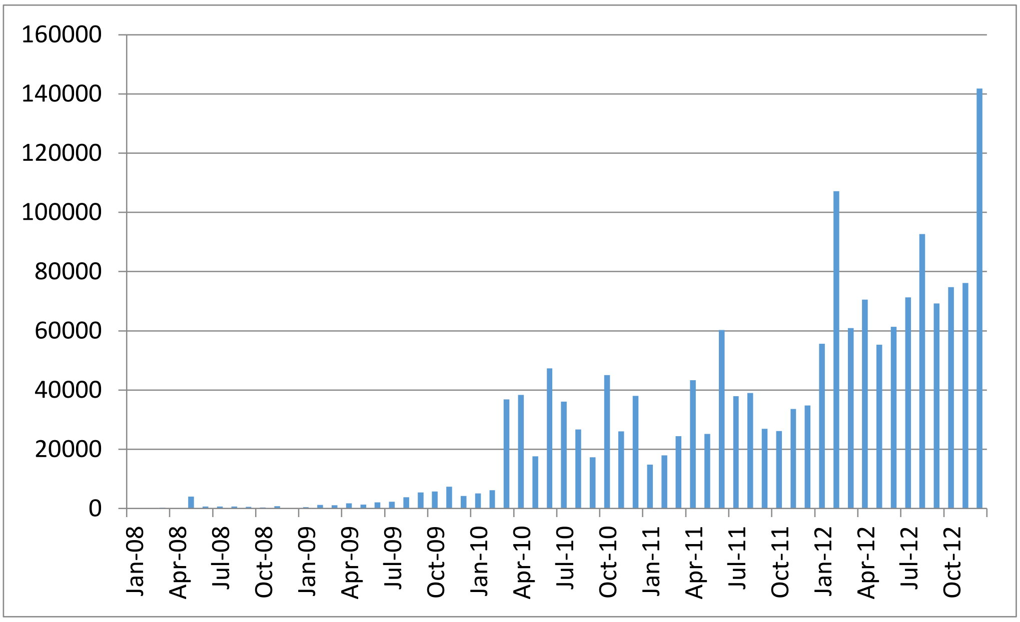


Figure 22: Number of Folders

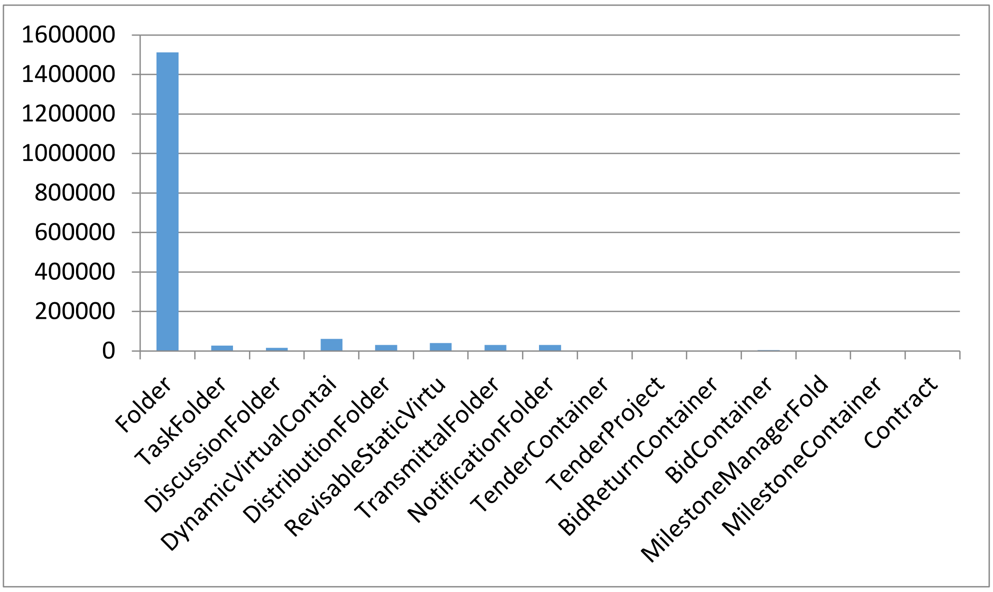


Figure 23: Number of Folder Types

Figure 23 illustrates the different folder types that exist within the system:

The next level down from Folders is Documents. Figure 24 below demonstrates the number of documents created per month across all projects.

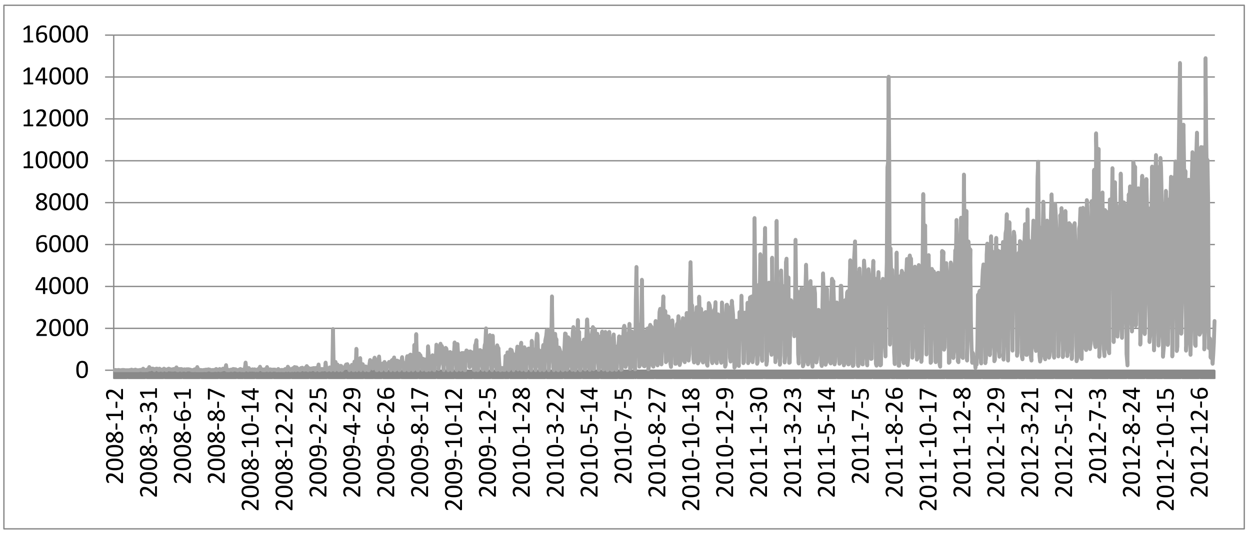


Figure 24: Number of Documents

There were 70 different file types within the system. Table 11below demonstrates the most popular file types used within the system

Table 11: Number and Percentage of File Types

File Types	Total Number	% of Total Number
PDF	2642444	61.76
JPG	306186	7.15
TXT	232331	5.43
DOC	243812	5.69
XLS	163700	3.82
DWG	424118	9.91
DAT	51235	1.19
DOCX	58685	1.37
ZIP	87261	2.03
DWF	70466	1.64

The system integrates with users' e-mail accounts in order to notify them of any recent changes, updates or incomplete tasks. The system holds information about notifications, tasks or discussions that has been sent to users or has been replied via e-mail. Therefore, e-mails were also explored to see whether there has been an increase in the amount of e-mail. Figure 26 illustrate an increase in the number of e-mail that has been sent or received from the system.

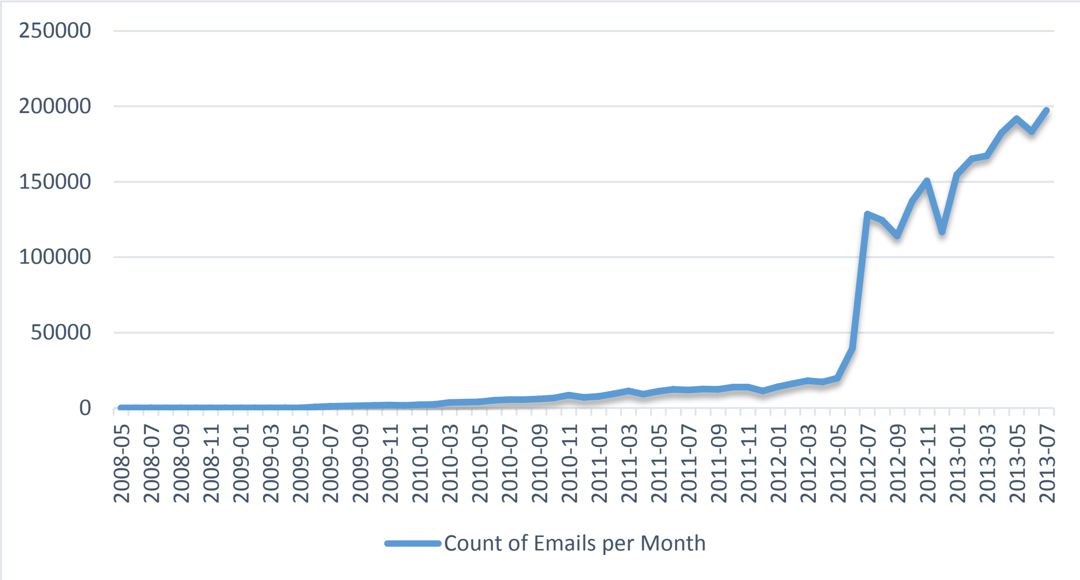


Figure 26: Number of Emails per Month

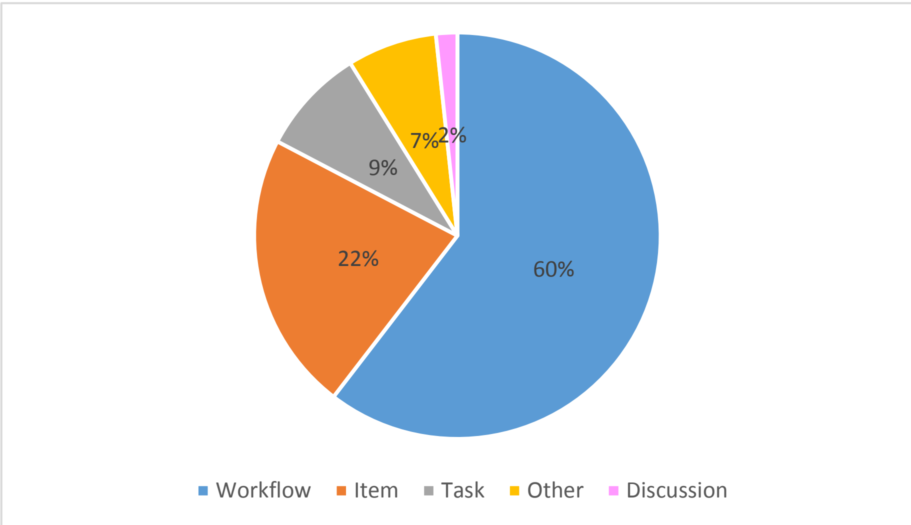


Figure 25: E-mail Types

Figure 25 illustrates that not all e-mail were discussion related, some are notifications automatically generated as a result of a task items and a workflow configuration. It also demonstrates the proportion of the different e-mail types existing within the system. Once the initial step of data mining was complete, a more detailed analysis of the data-set was undertaken to understand the relationship between project characteristics and level of electronic communication to indicate whether there has been an increase in electronic communications. An initial step in this stage was to compare the amount of information, including the minimum, maximum, mean and standard deviation values that was uploaded/downloaded onto the site, number of documents and number of active users across all useful and completed projects regardless of their duration, size and complexity. Figure 27, Figure 28 and Figure 29 show the results of this exercise, with Standard Deviation on second axis. For the full raw data-set please refer to Appendix I.

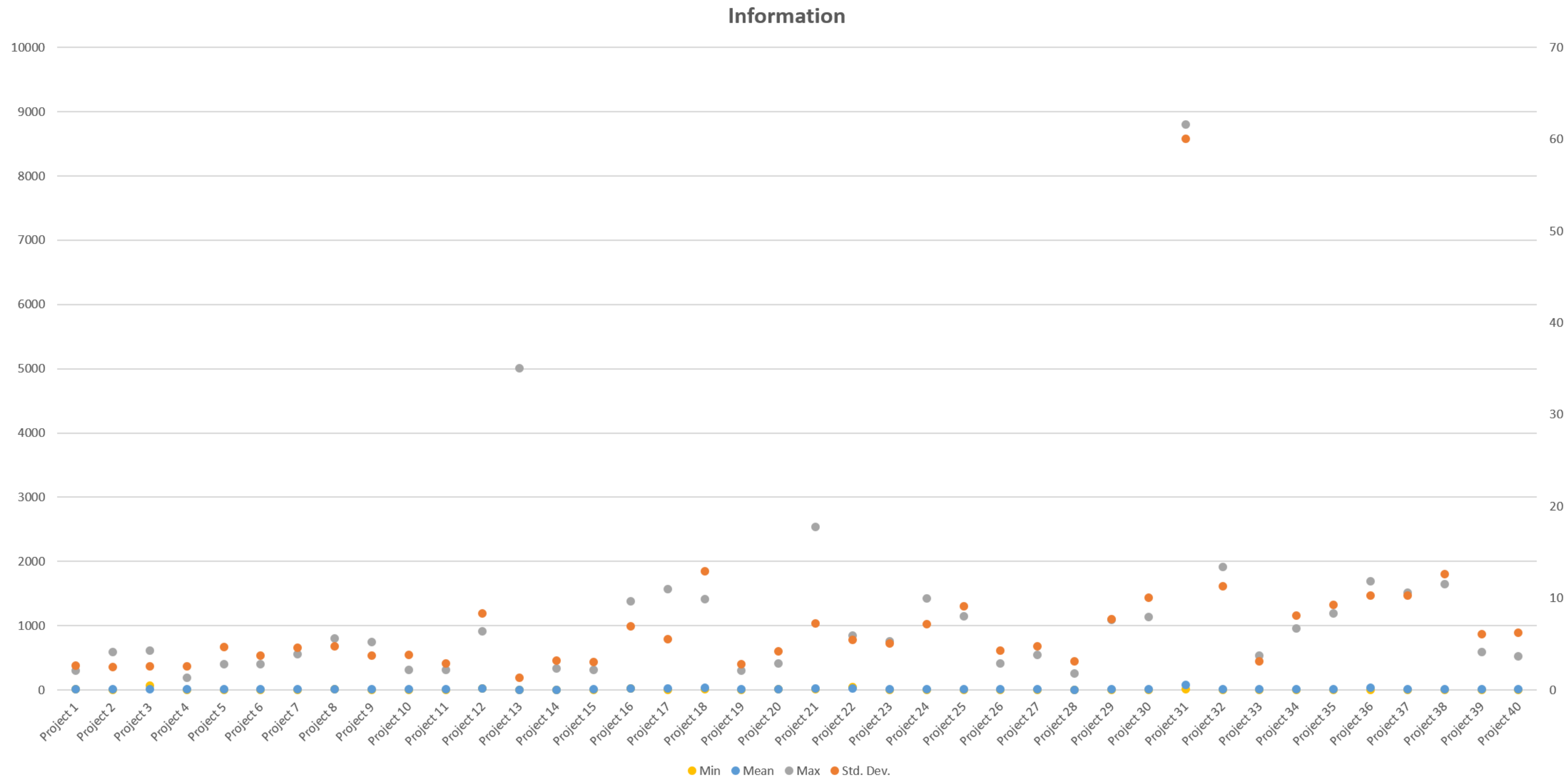


Figure 27: Min, Max, Mean and Std. Deviation values of information exchanges across projects

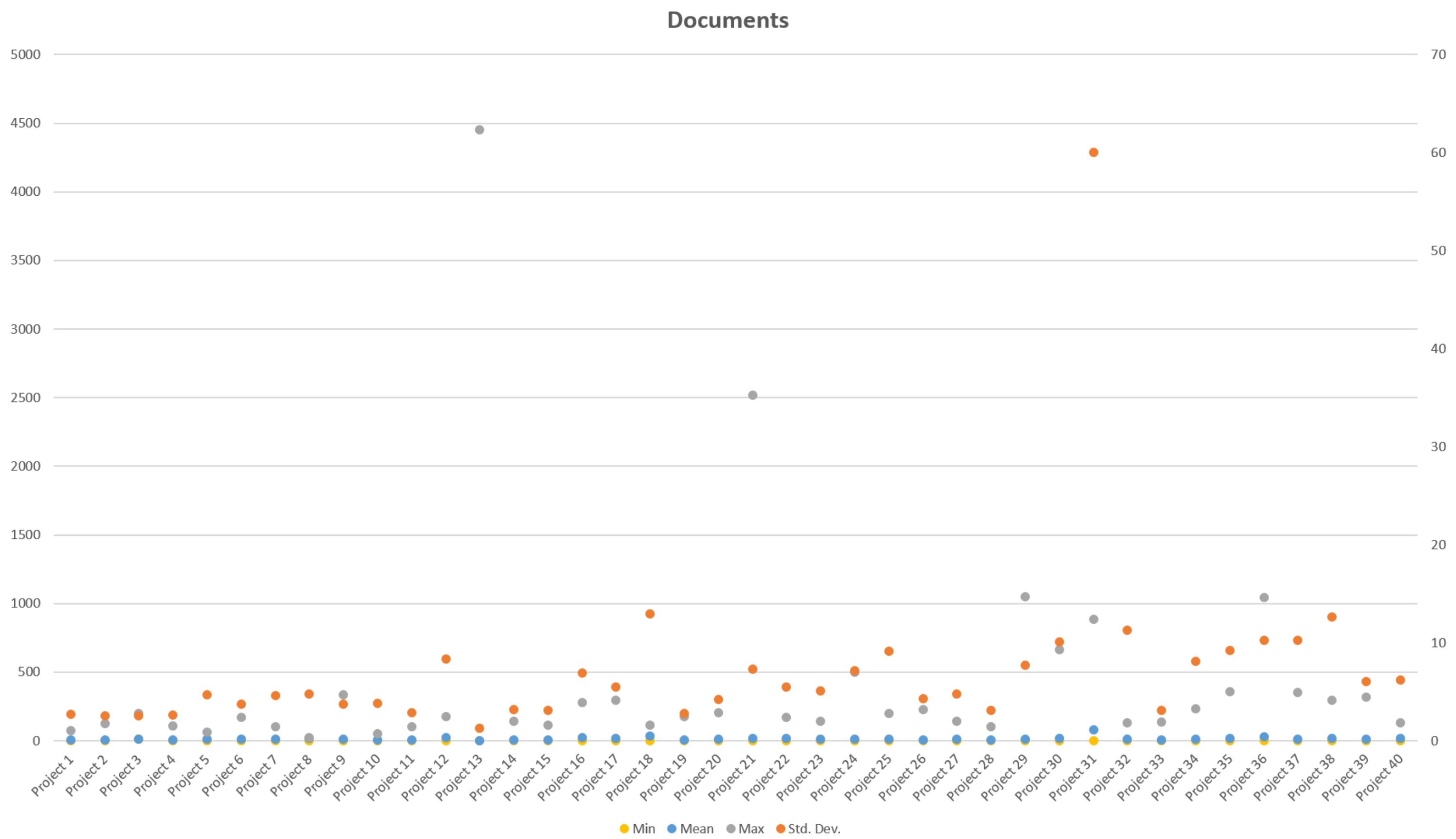


Figure 28: Min, Max, Mean and Std. Deviation values of documents created across projects

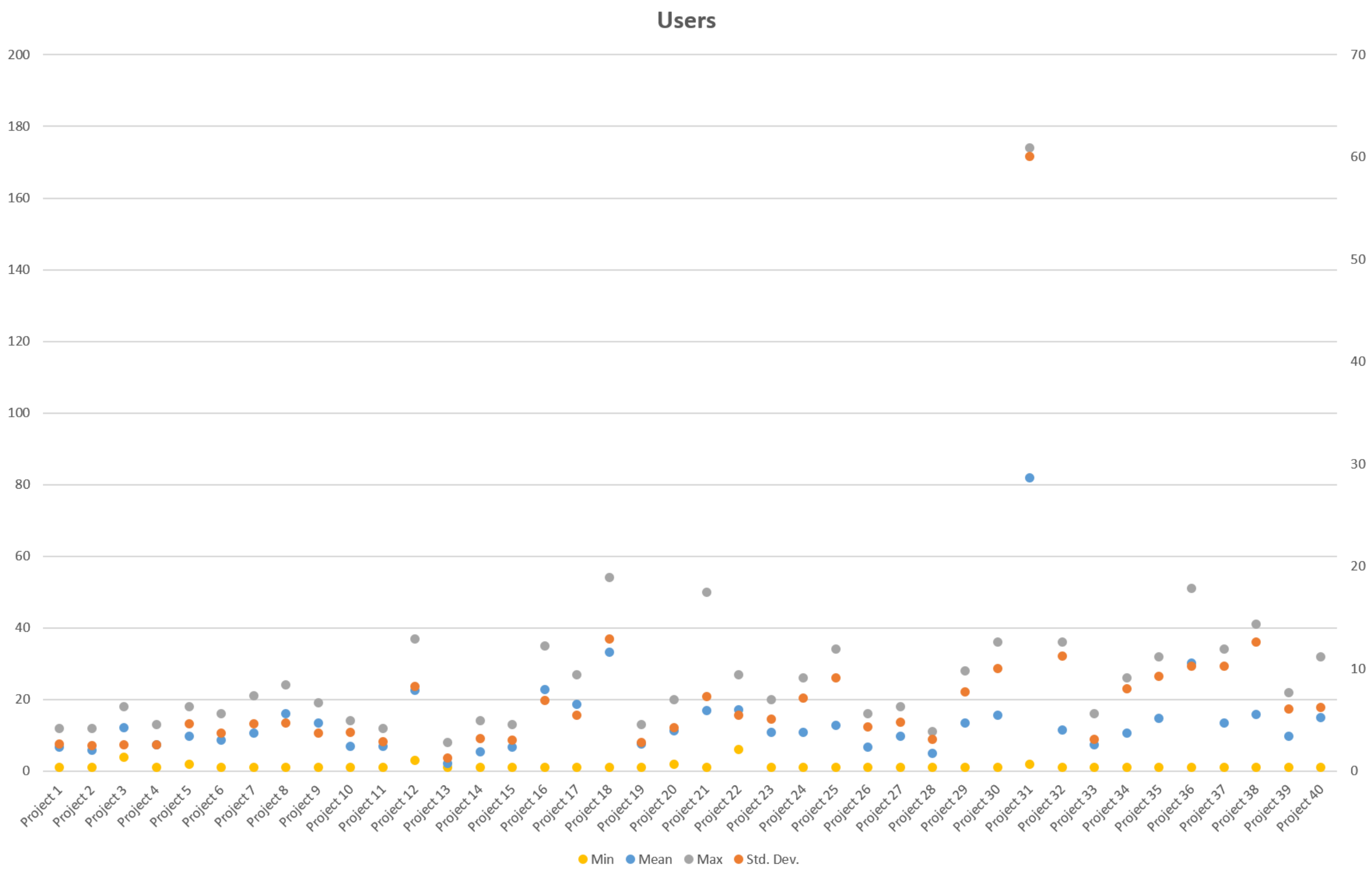


Figure 29: Min, Max, Mean and Std. Deviation values of active users across projects

Evaluation of discovered Knowledge – Step 1

Figure 27, Figure 28 and Figure 29**Error! Reference source not found.** illustrate the mean, tandard deviation, minimum and maximum number of information, documents and users per project. For the actual raw data-set please refer to Appendix I. The results demonstrate a number of issues;

- There is a wide range (i.e. significant gap between minimum and maximum values) in the amount of information that has been uploaded and downloaded. For example, the minimum number of information exchanges for project 17 is 2 and the maximum number is 1571, while project 21 has a minimum information exchange value of 8 and maximum number of 2533. This means that in some weeks there has been no information exchanged and in some weeks a lot of information has been uploaded and downloaded from the system. The same applies to the number of users and number of documents created. For example, minimum value for users for project 18 is 1 and maximum value is 54 and project 18 has a minimum value of 1 and maximum value of 54. This means that there had been more users active on the system and more documents created in some weeks than in others.
- Almost all of the projects have a high standard deviation value for information exchanges, which means the number of information exchanges in this data sample is spread over a wide range. Some have a higher value than the mean; for instance, project 2 has a mean of 119.15 and a std. deviation of 126.684 which means the variation of amount of information exchanged and the mean for this project are not representative. The same applies to documents; all projects have a high std. deviation value for documents created and some have a higher value than the mean. For instance, project 13 has a mean value of 189.84 and a std. deviation of 852.359. Although users all have high standard. deviation values too but none of the values are higher than the mean which indicates that the variation of users and the mean are more representative compare to information exchanges and documents.
- The lowest mean value for information is 67.71 (project 28) and the highest mean value is 2904.20 (project 31). The lowest mean value for users is 4.90 is (project 28) and the highest mean value is 81.97 (project 31). The lowest mean value for documents is 6.06 (project 33) and the highest mean value is 189.84 (project 13).

The next step in the data mining process was to undertake further analysis on different phases of each project to develop further understanding of how the level of electronic communication changes at each project phase

6.1.4.2 Data Mining – Step 2

During each project phase, project participants produce and communicate project information (e.g. drawings). The production and communication of information requires a high level of information processing, management and coordination (Peansupap & Walker, 2006). A European construction research and development project found that about 400 documents or document revisions are created for every million pounds worth of project value (Crotty, 2012). The production and communication of information are believed to be time consuming activities which form part of the project cost which is spent on creation and transaction of information (Mascitelli, 2002).

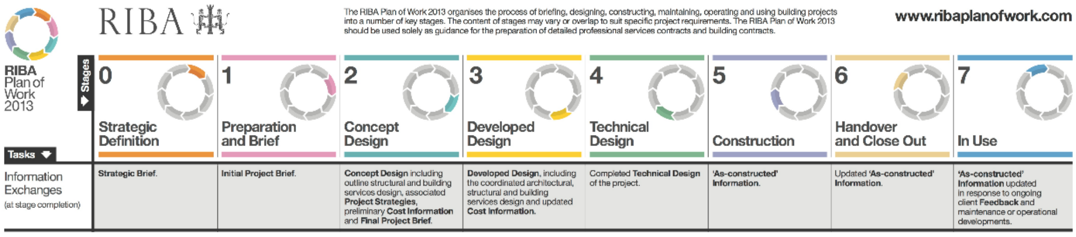


Figure 30: RIBA Plan of Work

Crotty (2012) argues that documents make ‘lower value’ administrative positions a necessity to ensure document registers, change protocols, request for information, filling systems and etc. are all managed and maintained appropriately.

Table 12: Cost Estimation per Project Phase

RIBA Stage	Description	Fee	Cumulative Fee
A+B	Appraisal + Feasibility	Time Charge	Time Charge
C	Outline Proposal	15%	15%
D	Detail Proposal	15%	30%
E	Final Proposals	20%	50%
F,G + H	Production Information +Tender	20%	70%
J	Pre-Contract Planning	2%	72%
K	Construction Works	25%	97%
L	Completion	3%	100%

Therefore, this step of the data mining process is concerned with project phase efforts and cost estimate associated with each phase based on a number of cost estimating guides. Cost estimates are a prediction of the total cost for the overall scope of a project based on all the resources (PMSS, 2013; APUC, 2011; GSA, 2007).All 40 projects were categorised by their duration and all project phases were aligned with RIBA Plan of Work (shown in Figure 30) utilising cost estimation methods. The amount of information uploaded and downloaded at each project phase was compared with other projects of similar duration.

The cost estimate associated with each phase (as demonstrated in Table 12) was applied to each project to find the phases and ensure alignment with RIBA Plan of Work stages. An example of this exercise can be found in Appendix G. This step of the data mining process was concerned with the comparison of amount of information exchanged (uploaded and downloaded) between different phases of projects aligned with RIBA plan of work. Table 13 demonstrates the mean value of different phases for 1-2 year duration projects. For rest of the projects please see Appendix J.

Table 13: Information Mean Value per Project Phase for 1-2 year duration Projects

Information	Phase 1		Phase 2		Phase 3		Phase 4		Phase 5		Phase 6	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
Project 1	47.10	35.72	87.7	57.343	97.31	66.61	105.54	52.02	96.50	71.23	16.00	4.24
Project 2	48.11	40.61	196.44	151.798	201.58	144.20	160.36	126.89	38.94	34.67	11.50	0.71
Project 3	184.10	57.57	342.2	120.226	393.54	142.91	298.86	106.28	192.61	61.14	161.00	52.33
Project 4	58.90	36.25	66.56	44.071	84.07	36.25	80.92	44.31	64.89	43.81	78.50	65.76
Project 5	51.86	83.68	167.5	111.719	86.33	53.60	123.56	77.22	234.00	87.47	182.00	.
Project 6	19.44	29.20	184.22	112.979	209.5	105.81	125.58	51.07	114.75	53.78	103.50	9.19
Project 7	66.89	62.23	250.89	122.922	352.55	130.51	147.17	66.61	68.63	41.28	6.00	5.66
Project 8	113.20	83.86	292.1	97.2	290.69	98.27	356.29	193.88	304.00	83.83	249.00	96.17
Project 9	157.88	128.34	339	89.732	500.45	102.13	517.55	129.67	448.33	133.89	332.00	33.94
Project 10	114.00	102.96	132.7	47.006	150.08	72.89	62.92	44.61	34.11	24.83	2.00	1.41
Project 11	78.78	60.89	73.1	78.474	109.58	83.23	131.00	83.01	117.71	63.38	57.00	24.04
Project 12	192.80	123.74	398.8	133.718	496.21	151.76	517.23	225.41	607.50	166.16	692.00	62.23
Project 13	1439.14	2204.65	8	5.806	13.8	11.76	5.78	4.30	7.64	9.35	11.00	.
Project 14	62.44	66.09	86.7	62.1	147.08	91.10	67.15	63.41	61.31	62.45	3.50	3.54
Project 15	33.57	31.73	144	72.042	145.22	82.10	92.56	51.15	46.92	30.22	43.00	.
Project 16	281.40	290.98	655.91	175.452	1015.14	191.59	830.15	232.12	455.05	156.46	298.50	3.54
Project 17	359.90	300.52	396	153.133	869.31	280.45	902.54	342.87	557.88	220.52	424.00	90.51
Project 18	256.00	268.99	839.22	262.428	840.17	431.74	850.64	238.85	437.88	127.46	461.00	45.26
Project 19	64.13	94.46	138.88	62.403	93.55	45.17	131.73	70.48	79.43	20.31	41.50	19.09
Project 20	107.00	106.49	156.4	98.782	248.23	89.31	208.31	66.26	178.06	71.10	207.00	106.07
Project 21	405.40	783.18	102.3	59.412	373.71	325.22	277.92	180.01	509.72	529.10	279.00	125.87
Project 22	501.11	187.72	520.89	172.984	485.5	129.16	278.83	105.38	160.38	60.36	86.50	30.41

Evaluation of Discovered Knowledge – Step

Table 13 illustrates the mean and standard deviation of amount of information exchanged per phase per project. The results demonstrate that again almost all projects have a high standard deviation value, which means the number of information exchanges are spread over a wide range. Some of the projects for instance project 21 has a standard deviation value of 783.178 and a mean value of 405.40 for phase 1 of the project or project 24 has a standard deviation value of 249.909 and a mean value of 101.81 for phase 5 which means the data is not normally distributed and the variation of information exchanges and the mean are not representative, i.e. the mean value is not significant. The value of standard deviation for some projects such as Project 1, becomes less than the mean value as the project progresses (i.e. later phases) which means the mean value for these phases is a good indication of information exchange distribution. Although these projects have the same duration the mean value varies a lot, for instance for projects with 1-2 years duration at phase 5 the lowest mean value is 7.64 and the highest value is 607.50 or for projects with 3-4 years duration at phase 1 the lowest mean value is 44.42 and the highest value is 1983.23.

The next step of the data mining process was to undertake the same process and method of analysis on the amount of documents created at each project phase as it is believed that the effort and the time it takes to create documents is greater than uploading/downloading information which has already been created.

6.1.4.3 Data Mining – Step 3

The amount of documents created at each project phase was compared with other projects of similar duration. This step of the data mining process was concerned with the comparison of amount of documents created between different phases of projects aligned with RIBA plan of work. Table 14 demonstrates the mean value of different phases for 1-2 year duration projects. For rest of the projects please see Appendix K.

Table 14: Document Mean Value per Project Phase for 1-2 year duration Projects

Document	Phase 1		Phase 2		Phase 3		Phase 4		Phase 5		Phase 6	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
Project 1	13	19.026	22.3	24.24	16.92	18.209	15.46	19.324	13.72	19.634	4	2.828
Project 2	13	16.523	34.44	31.321	22.92	37.585	10.09	14.802	4.81	11.873	4.5	6.364
Project 3	55.3	57.758	57.5	27.581	91.85	50.915	59	25.979	36.83	17.175	31.5	2.121
Project 4	27.7	34.299	8.22	6.119	5.5	4.328	7.33	7.655	8.06	8.018	3.5	4.95
Project 5	14.43	14.842	20.17	23.216	9	17.081	10.89	14.836	8.42	6.417	10	.
Project 6	3.22	6.099	42.33	28.601	46.92	42.139	27	15.84	26.63	13.87	35	11.314
Project 7	17.78	22.055	23.11	16.058	30.27	20.499	14.42	28.903	6.75	12.25	0	0
Project 8	9.8	4.962	17	3.266	17.62	2.959	17.43	5.431	17.11	3.428	16	1.414
Project 9	56.13	112.058	45.22	9.795	72.18	21.484	85.36	30.107	67.87	25.991	55.5	0.707
Project 10	21.7	20.892	8.5	6.276	9.17	8.365	5	7.071	4.28	8.323	0	0
Project 11	30.44	34.257	7.2	9.028	2.92	5.16	4.83	12.097	2.94	11.872	7.5	10.607
Project 12	38.2	29.57	46.7	41.323	62.07	34.782	64.85	52.094	39	34.449	26	11.314
Project 13	1327.71	2012.411	0.88	2.1	0	0	0.11	0.333	0	0	0	.
Project 14	44.78	57.926	18	17.789	40.75	44.781	7.69	11.736	1.38	3.481	0	0
Project 15	21.14	24.674	42.29	38.53	13.67	11.413	13.44	13.52	1.75	3.696	0	.
Project 16	34.8	26.389	43.18	37.277	90.14	67.468	55.54	33.97	71.42	47.352	90	106.066
Project 17	55.6	88.627	43.78	65.603	33.31	26.32	30	14.793	15.82	11.97	7.5	4.95
Project 18	27.44	27.848	50.56	17.636	45.33	30.97	50.36	29.446	32.5	26.412	38.5	7.778
Project 19	29.38	59.493	0.75	1.035	2.64	7.131	6.36	12.925	0.29	0.611	1.5	2.121
Project 20	46.6	43.559	25.4	21.235	41.38	57.64	14.15	25.261	11.06	14.724	34.5	37.477
Project 21	369.3	790.064	10.6	9.131	18.64	9.516	69.31	56.256	160.28	358.73	19.5	3.536
Project 22	75.67	57.234	22.67	21.26	27.25	20.645	11.5	13.174	0.94	1.124	0	0

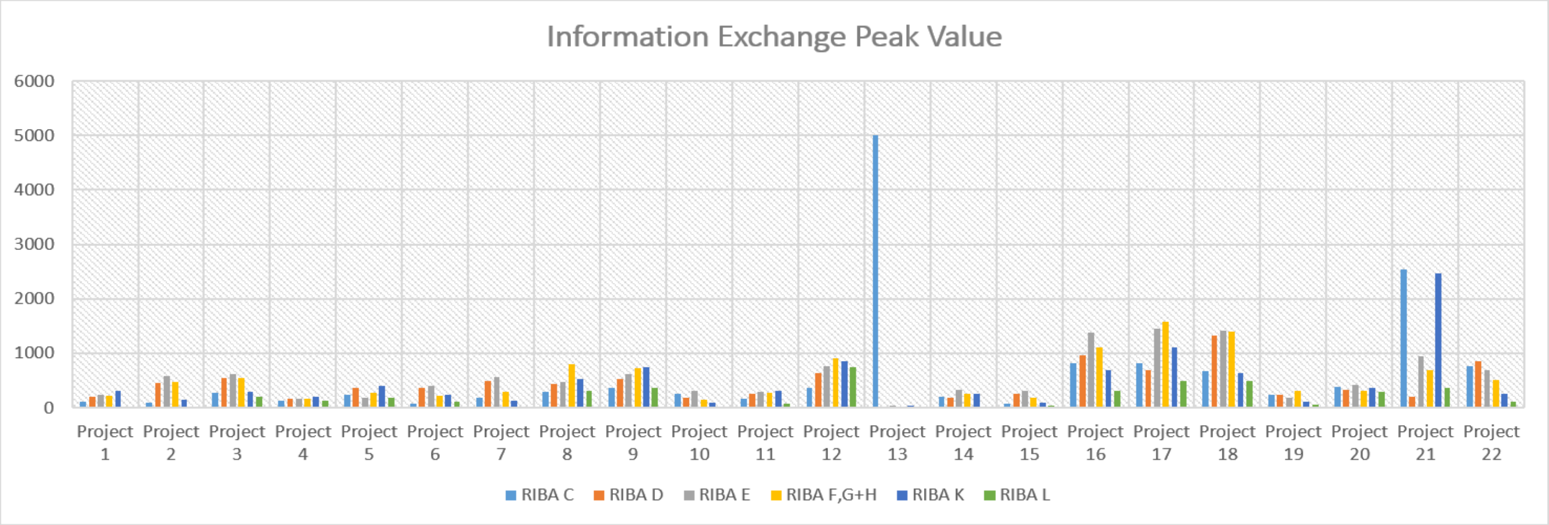
Evaluation of Discovered Knowledge – Step 3

Table 14 illustrates the mean and standard deviation of amount of documents created per phase per project. The results demonstrate that again almost all projects have a very high standard deviation value. In this case most of the projects have a higher standard deviation value than the mean and some projects such as Project 9 or Project 21 value of standard deviation is nearly double the value of the mean at phase 1. Same as information exchanges, although all the projects have been grouped into same duration categories the mean value varies a lot, for instance for projects with 2-3 years duration at phase 1 the lowest mean value is 13.11 and the highest value is 179.93 or for projects with 4-5 years duration at phase 6 the lowest mean value is 0 and the highest value is 235.14.

The next step of the process was to find the maximum value (peak value) of information exchanges and documents created for each phase of every project to plot a graph for each project.

6.1.4.4 Data Mining – Step 4

This step of the data mining process was concerned with finding the maximum value (peak value) of information exchanges and documents created for each phase of every project to plot a graph and overlay all the graphs with the same duration to visualise the trends and do a comparison of peak values.



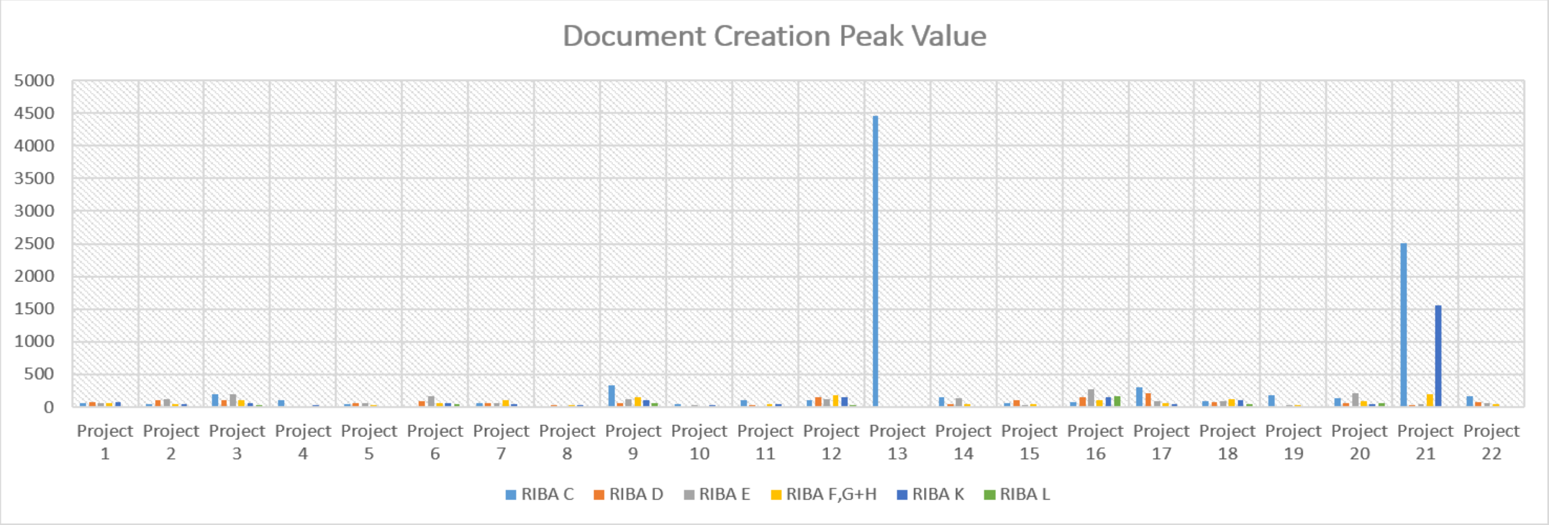
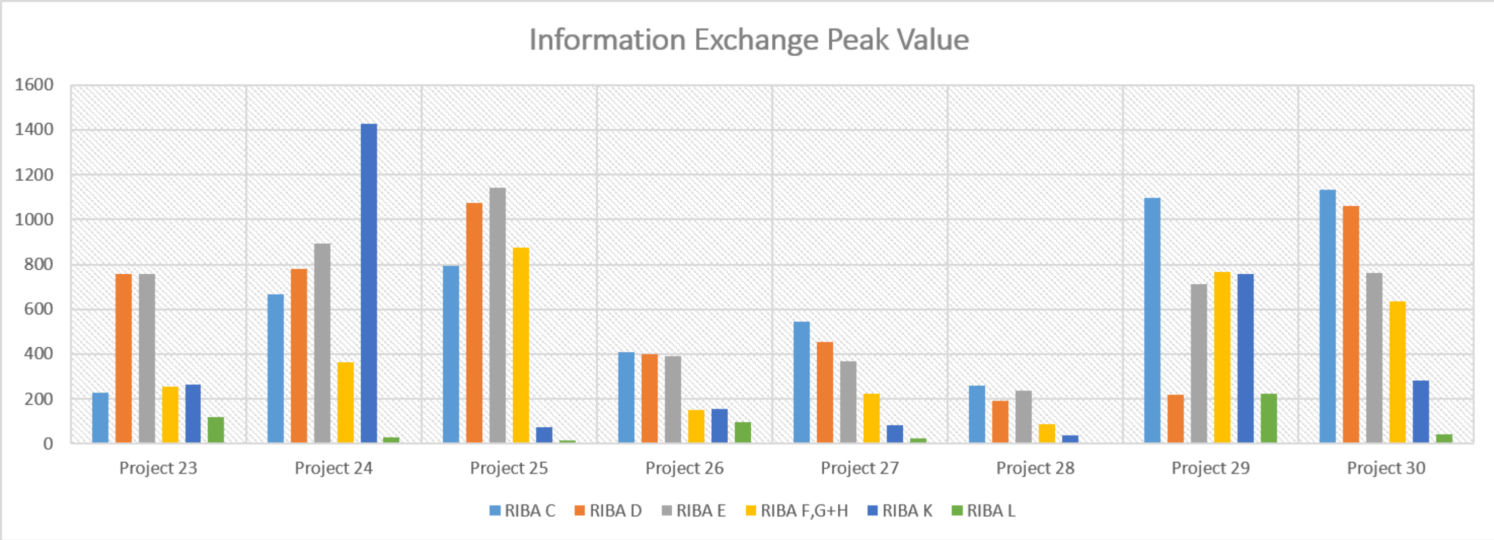


Figure 31 1-2 years Projects Peak Values (maximum number of information exchange and document creation per phase)



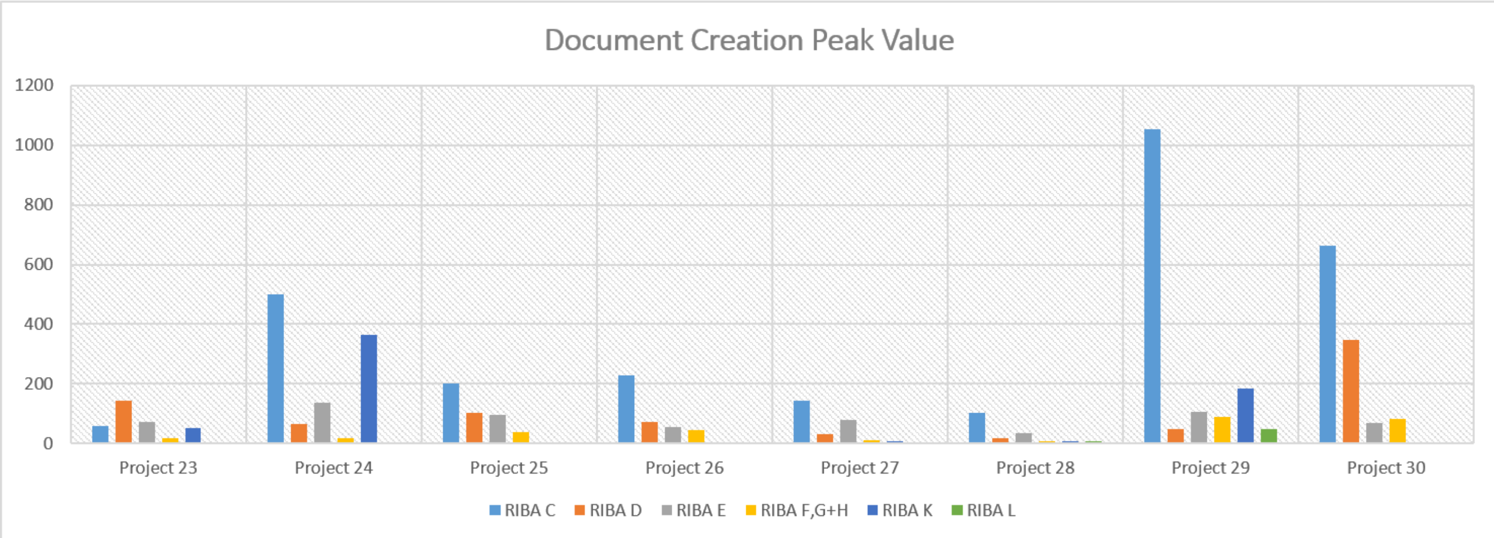


Figure32 2-3 years Projects Peak Values (maximum number of information exchange and document creation per phase)

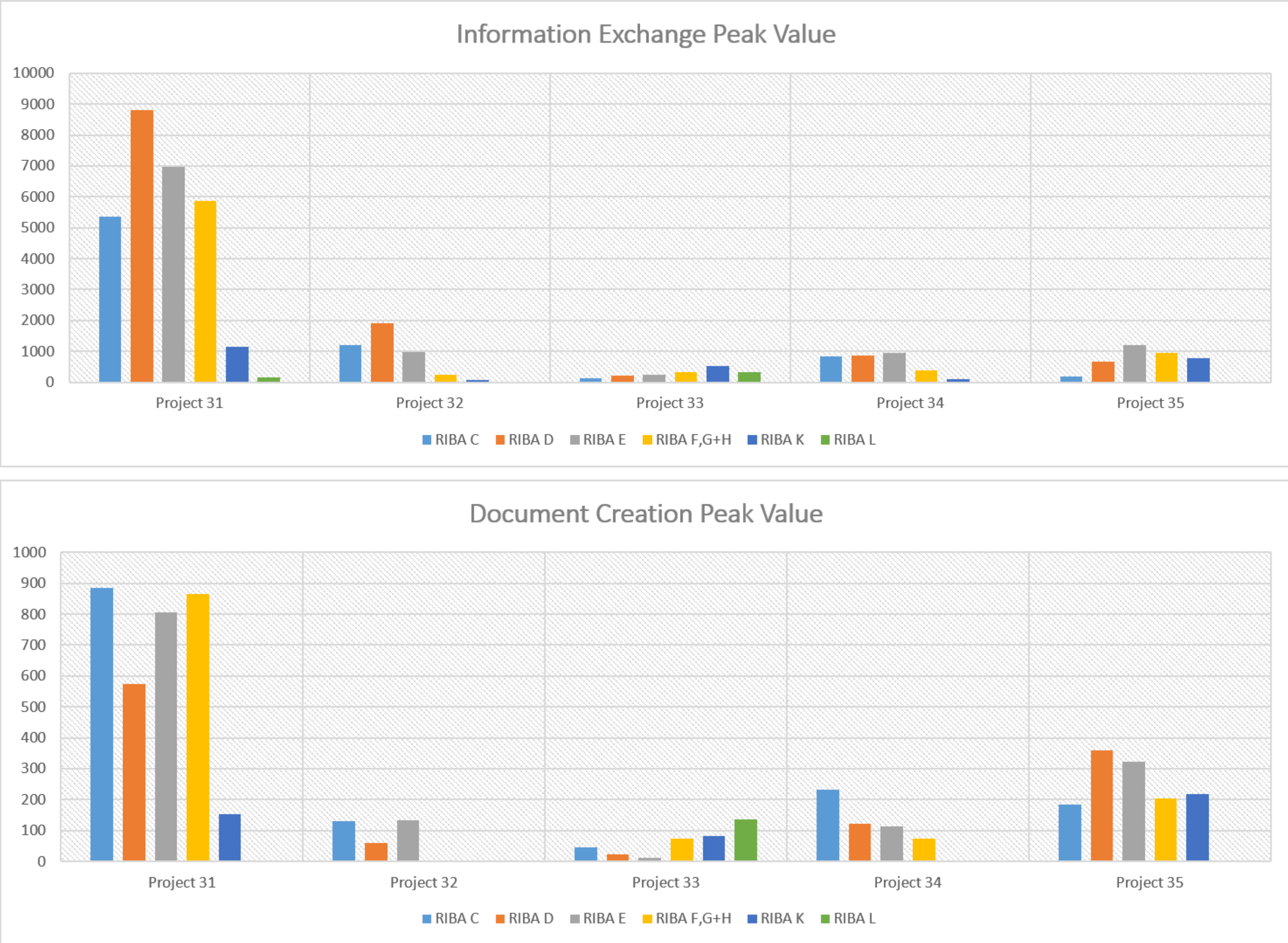
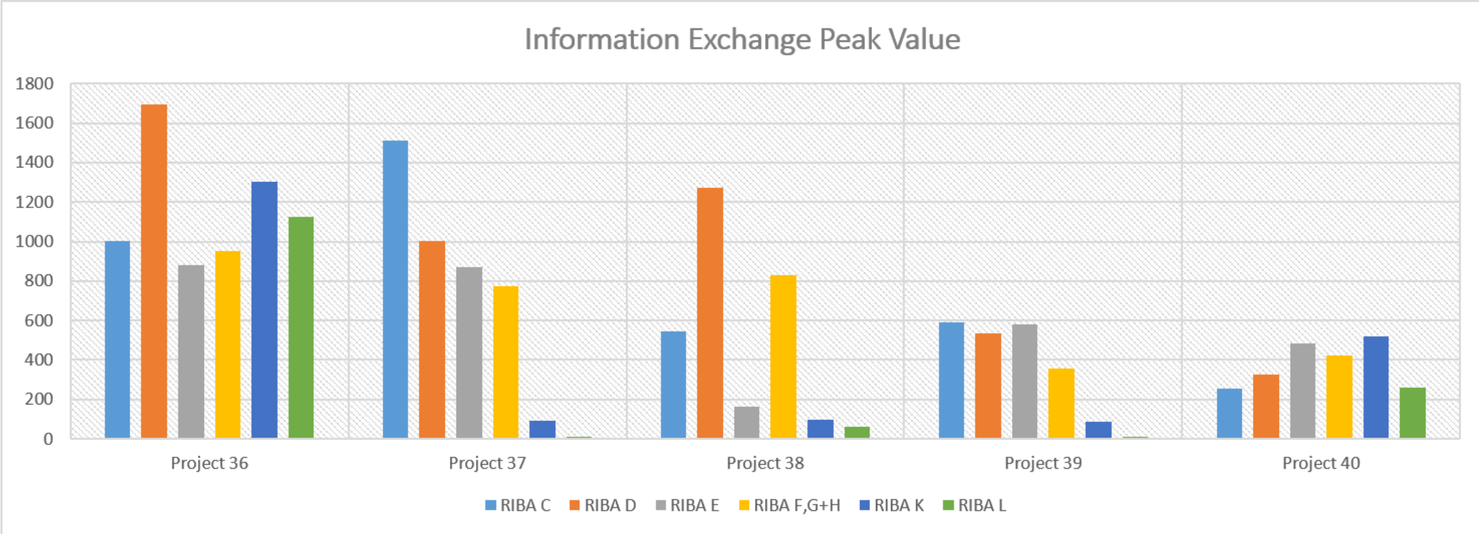


Figure33 3-4 years Projects Peak Values (maximum number of information exchange and document creation per phase)



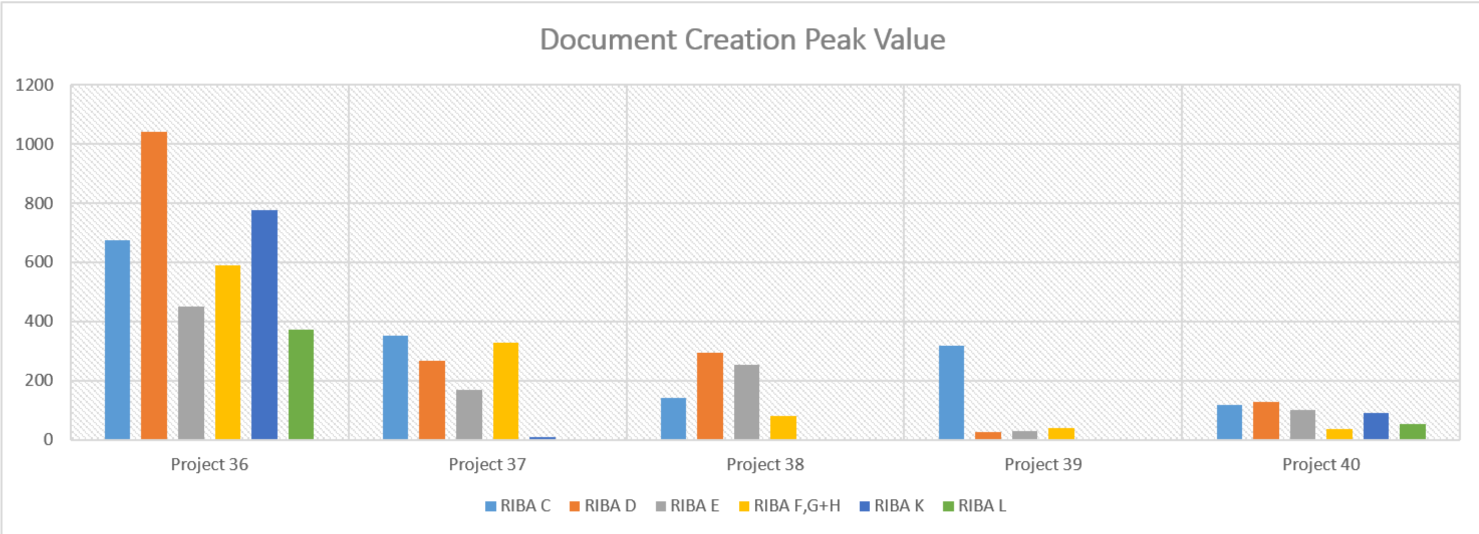


Figure34 4-5 years Projects Peak Values (maximum number of information exchange and document creation per phase)

Evaluation of Discovered Knowledge – Step 4

Figure31 , Figure32 , Figure33 , Figure34 above illustrate the maximum value of information exchanges and documents created per phase of every project. Studying the graphs closely, they can be categorised into 3 different groups, as shown in Table 15 and Table 16 based on their trends/graph shapes.

Table 15: Max value for Information

	High peak value at start	High peak value towards the end	2 or more peak values
Number of Projects	14	5	21

Out of the 40 projects, there are 14 projects that have a high peak value at the start of the project, 5 projects with a high peak value towards the end of the project and 21 projects with 2 or more peak values for exchanging information. This confirms the results from steps 1,2 and 3 that most of the projects do not have a normal distribution and the amount of information exchanges vary a lot. Some weeks you may have a lot of information exchanges and some weeks there may be no information exchanges.

Table 16: Max value for Documents

	High peak value at start	High peak value towards the end	2 or more peak values
Number of Projects	4	2	34

There are 4 projects with a high peak value at the start of the project, 2 with a high peak value at the end of the project and 34 projects with 2 or more peak values for creation of documents. Same as information exchanges, creation of documents also does not have a normal distribution. About 85% of projects have 2 or more peak values which illustrates that the amount of documents created vary.

High peak value of documents created or information exchanged at the start of the project patterns mean that those projects had a clear set of information requirements. The information requirements as well as communication protocols, processes and systems had been clearly defined, captured and cascaded throughout the supply chain to ensure every project member is aware of their role with regards to information production and information exchange. High peak value at the start of the project also means early engagement and involvement of the designers and contractors as well as clear set of validation and verification processes so that the information moves seamlessly through the workflow.

High peak value of documents created or information exchanged towards the end of the project patterns mean that those projects had no front understanding of their information requirements with very poor or no planning around communication protocols, processes and systems. It also means there was no engagement with designers and contractors until the project was ready for construction.

Two or more peak values of documents created or information exchanged throughout the project patterns mean that, although those projects had defined and communicated their information requirements and communication protocols, processes and systems, there were still many unknowns with ambiguous and incomplete information. It may also mean that validation and verification processes were not clearly defined, hence an increase in information flow to ensure the checking and approval of information. Also, due to insufficient information a lot of communication was required during construction.

Next step of the process was to find the correlation between number of users and the amount of information exchanged per project.

6.1.4.5 Data Mining – Step 5

This step of the data mining process was concerned with correlation between number of users and amount of information exchanged per project. The dependant variable was 'user' and the independent variable was 'information'. This demonstrated whether there are any relationships between the number of users and the amount of information exchanged and how strong the relationship is, for example; a change in the number of users will make changes in the number of information.

There are different techniques for correlation analysis, including those developed by, and named after Pearson and Spearman. Spearman's technique is concerned with the rank order measures and Pearson technique is concerned with the linear relationship and the strength of the relationship (Deacon *et al.*, 1999). Due to the nature of this research and the nature of the variables (i.e. they are continuous variables) Pearson's Correlation has been chosen.

Table 17: Correlation between amount of Information Exchanged and number of Users

Project 1	**User**
Information	.631**

Project 2	**User**
Information	.626**

Project 3	**User**
Information	.442**

Project 4	**User**
Information	.474**

Project 5	**User**
Information	.754**

Project 6	**User**
Information	.801**

Project 7	**User**
Information	.820**

Project 8	**User**
Information	.719**

Project 9	User
Information	.704**

Project 10	User
Information	.798**

Key: *$**P<0.01$ and $*P<0.1$*

01

Please see Appendix L for the rest of the tables.

Evaluation of Discovered Knowledge – Step 5

As explained, correlation analysis demonstrates whether 2 variables are related. It also measures the strength of the linear relationships between the 2 variables. Linear relationships could either rise or fall, which is also known as the direction of the correlation.

Table 17 demonstrates the output of the correlation analysis and illustrates the fact that all projects show a positive correlation (a positive direction) which meaning that as the number of users increases the number of information exchanges also increases. Correlations also illustrate significance: the so-called ‘P-value’. A P-value of less than 0.5 (P = <0.5) indicates that the result is not likely to be random (i.e. it is significant) which means the result is likely to be true in the population and can be used to generalise the findings. All the correlations are less than 0.5 in this case.

Table 18: Information Exchange and User Correlation Strengths

Value of Pearson’s ‘r’	<.3	<.5	<.7	<1
Number of Projects	0	6	9	25

Although all outputs demonstrate a strong relationship between the 2 variables amongst all projects, some have a stronger relationship (the closer to 1 the value is, the stronger the relationship). Table 18 illustrates the number of projects with different strengths in relationship. As shown, there are 25 projects with a correlation more than r= 0.7 which means these projects have a very strong positive correlation. There are 9 projects with a correlation more than r= 0.5 and 6 projects with a correlation more than r= 0.3.

6.1.4.6 Data Mining – Step 6

This step of the data mining process was concerned with correlation between number of users and number of documents created per project. The dependant variable was ‘user’ and the independent variable was ‘document’. This demonstrated whether there are any relationships between the number of users and the number of documents created and how strong the relationship is, for example; a change in the number of users will make changes in the number of documents created on the site.

Table 19: Correlation between amount of Documents created and Number of Users

Project 1	**User**
Document	.268*
**P<0.05*	

Project 2	**User**
Document	.433**
***P<0.01*	

Project 3	**User**
Document	.156

Project 4	**User**
Document	-.309*

Project 5	**User**
Document	.241

Project 6	**User**
Document	.418**

Project 7	**User**
Document	.423**

Project 8	**User**
Document	1.000**

Project 9	**User**
Document	.169

Project 10	**User**
Document	.287*

Key: ***P<0.01 and *P<0.1*

Please see Appendix M for the rest of the tables

Evaluation of Discovered Knowledge – Step 6

Table 19 demonstrate the output of the correlation analysis and illustrate that unlike information exchange and users, documents and users do not all show a positive correlation.

For instance Project 24 has a negative correlation of r =-.025, which means as the number of users increases the number of documents decreases. However, Project 8 has the strongest correlation with value of r= 1.0 which means all data points fall on a straight line.

Table 20: Documents and Users Correlation Strengths

Value of Pearson's 'r'	<.3	<.5	<.7	<1
Number of Projects	23	9	7	1

Unlike information exchanges, about 58% of the outputs from document correlation analysis demonstrate a weak relationship between the 2 variables. Table 20 illustrates the number of projects with their different strengths in relationship. As shown, there are 23 projects with a correlation less than r= 0.3 which means these projects have a very weak correlation. Some of these 23 projects have a negative correlation. There are 9 projects with a correlation less than r= 0.5 and 7 projects with a correlation less than r=0.7.

6.1.4.7 Data Mining – Step 7

This step of the data mining process was concerned with developing a mathematical formula which best fits the data between the number of users and the number of information exchanges. As number of documents and number of users were not all correlated with a positive correlation and there were inconsistencies in the correlation outputs, it was decided to undertake regression analysis on number of users and information exchanges only. Regression analysis is utilised on continuous data sets to predict future trends (Deacon *et al.*, 1999). However, the data-set in this study is not continuous and future trends are highly dependent on project size, complexity and procurement methods. Therefore, the purpose of regression analysis for this research study is to measure the effect number of users would have on number of information exchanges.

Table 21:Regression between amount of Information Exchanged and Users

Project 1

	b	SE B	β	p
Constant	-9.073	15.918		.571
User	14.504	2.226	.631	.000

Note, R^2_{adj}= .399; F(1,64)=42.442, p<.001.

Project 2

	b	SE B	β	p
Constant	-63.912	32.886		.057
User	31.581	5.213	.626	.000

Note, R^2_{adj}= .392; F(1,57)=36.702, *p*<.001.

Project 3

	b	SE B	β	p
Constant	2.034	69.957		.977
User	22.241	5.605	.442	.000

Note, R^2_{adj}= .195; F(1,65)=15.749, *p*<.001.

Project 4

	b	SE B	β	p
Constant	15.494	13.902		.269
User	7.534	1.761	.474	.000

Note, R^2_{adj}= .225; F(1,63)=18.302, *p*<.001.

Project 5

	b	SE B	β	p
Constant	-21.541	24.254		.380
User	16.616	2.232	.754	.000

Note, R^2_{adj}= .569; F(1,42)=55.434, *p*<.001.

Project 6

	b	SE B	β	p
Constant	-41.856	18.545		.028
User	20.171	1.981	.801	.000

Note, R^2_{adj}= .641; F(1,58)=103.713, *p*<.001.

Project 7

	b	SE B	β	p
Constant	-103.847	26.856		.000
User	24.867	2.302	.820	.000

Note, R^2_{adj}= .672; F(1,57)=116.672, *p*<.001.

Project 8

	b	SE B	β	p
Constant	-56.683	42.166		.184
User	20.895	2.509	.719	.000

Note, R^2_{adj}= .516; F(1,65)= 69.371, *p*<.001.

Please see Appendix N for the rest of the tables

Evaluation of Discovered Knowledge – Step 7

In above equations, R^2 is similar to correlation coefficient and it is the amount of variability in information exchanges due to variability in the amount of users. Thus, the amount of variability in information exchanges is the attribute whose value is to be determined by a linear combination of attributes B and attribute Beta. B is the amount of information exchanges that increases per user and attribute Beta puts B into perspective/context. B is between 0-1, the higher B is the higher impact it would have and 46% variance means that amount of information depends on the number of users (% shows the variance).

For instance, for Project 1 ‘number of users’ explained 40% of the variance of information exchanges. This amount of variance explained was statistically significant (Note, R^2_{adj} = .399; $F(1,64)=42.442$, $p<.001$). Specifically, the amount of information exchanges increased by 14.5 per every unit increase in users. This increase was also statistically significant ($B=.63$, $p<.001$)

6.1.5 Use of the discovered knowledge

The final step is to present the new insights gained in Chapter 7 and makes sense of the data mined patterns in relation to the research aims and objectives. The objectives of this study, as covered in section 1.4.3 of Chapter 1 are revisited and answered in the following chapter.

CHAPTER 7 –FRAMEWORK DEVELOPMENT

After carefully reviewing the literature and undertaking the pilot study and the focus groups, it was evident that the industry is still bound to conventional ways of communicating project information, which are disjointed, unstructured and ad-hoc, using tools such as e-mail. It was also apparent that the success of construction projects is heavily determined by effective communication, and therefore it is recommended that the industry looks deeper into the communication processes and clearly identify and document communication requirements to improve, and where required re-engineer these processes. To this end, it was clear that practitioners within construction industry can benefit from a clear set of characteristics outlining an effective communication framework and strategy for implementing BIM at project level. As a result, a Project Communication Maturity Model, (Figure 35), based on the BIM wedge and CSCW principles was developed, to provide a comprehensive metrics according to which communication patterns can be evaluated during BIM implementation.

This maturity model identifies 4 levels of communication based on efforts both within construction and other sectors to develop such maturity models:

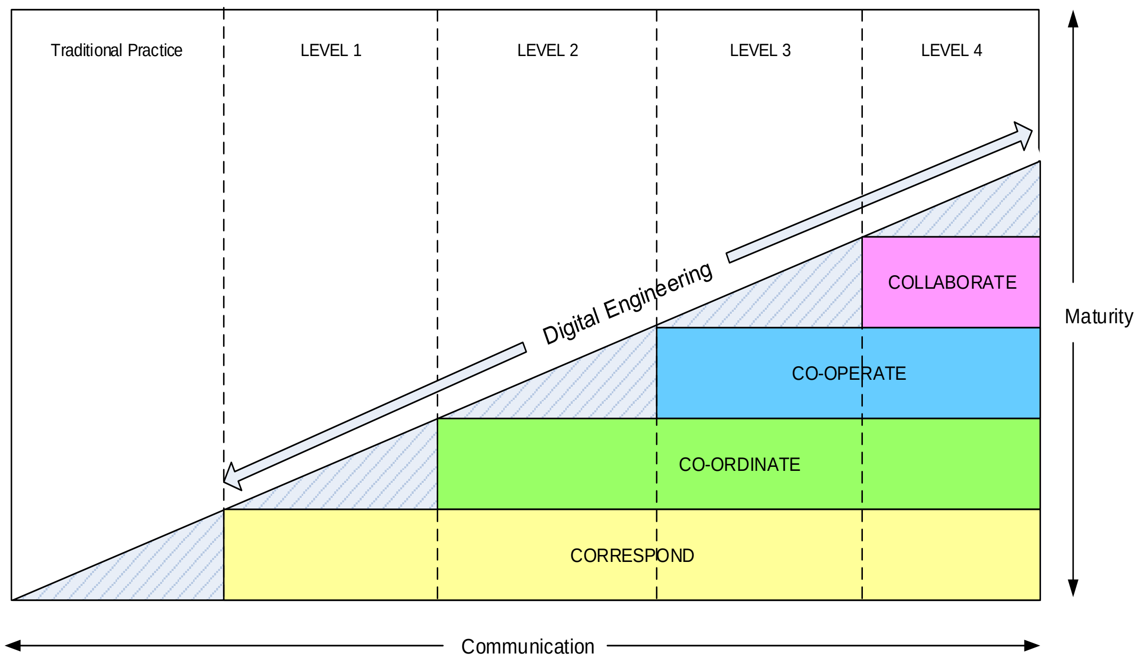


Figure 35: Project Communication Maturity Model (4C's)

The Project Communication Maturity Model (4 C's) represents the capabilities that should be offered at different levels in a federated working environment (i.e. construction projects). The 5 levels of capability (step changes) in the model demonstrate the major landmarks at which organisations and project teams within those organisations are exhibiting the capabilities on that level. Each level has its own characteristics which enable organisations and projects run within those organisations to increase their communication maturity in a precise way. The traditional practice level, which is the level 0, relates to projects that do not utilise ICT and are still bound to traditional ways of working. The other 4 levels are fixed and the ratio of importance for each maturity is the same; they are all equally as important and there is no quantification of maturity or any significance to the height of the bars. Each level can produce the outcomes of previous levels, even though these outcomes may not be required as a deliverable. This framework can be applied to any construction organisation or projects utilising BIM or CAD or any other 3D visualisation software. These technologies can be employed at any level, also information can be exchanged at any level of maturity; an important factor is “how” information is exchanged. Table 22 expands on the 4C’s model and demonstrates the characteristics required at each maturity level.

Table 22: Characteristics required at each 4C's Maturity Level

Capability	Explanation	People	Process	Characteristics	Technology
Correspondence	Transmitting and receiving data with no pre-agreements.	Working knowledge of Computer Aided Design (CAD)	Ad-Hoc	Unsolicited Unmanaged Unstructured	FTP links and E-mail.
Co-ordination	Agreed workflows and standard structure for data production using: BS1192 and PAS1192 suite of documents	Working knowledge of CAD and implementation of BIM standards. Understanding of personal roles and responsibilities	Automation	Managed Structured	Intranets, Extranets. Groupware, Document Management and Records Management Systems.
Co-operation	Mutual benefit, interaction and commitment between organisations with managed communication using PFI and BIM Protocol	Working knowledge of object-based modelling and systems engineering disciplines. Identifying data requirements	Initial Workflow Integration, System Synchronisation, Change Management and Version Control	Managed Structured Contractually Mandated Consequentially Significant	Customised Intranet, Extranets, Common BIM Platform, BIM Library Framework and BIM Execution Plan.
Collaboration	Shared information, risks and liability, high level of communication and trust required.	Computer and information scientists with working knowledge of big data, data analytics and digital engineering	Full workflow Integration (Integrated Project Delivery methods) Shared Resources Real-time Pipeline	Shared Goals Pre-defined Consequentially Insignificant	BIM

Analysis on the utilisation of BIM, as a collaborative tool, will be explored further in section 7.2.

7.1 Integrated Communication Processes

The purpose of this section is to discuss the following research questions:

- Will the implementation of discipline-based information models and the use of traditional working practices increase electronic communication?

- Is e-mail an effective means of communication for BIM enabled construction projects?

Chapter 5 demonstrated a wide range of concerns around communication practices within Construction projects. These issues, according to the pilot study and focus groups participants are due to the growth of the industry in relation to technology, organisations size, project complexity, cultural changes and innovation, but the industry is still bound to traditional and inconsistent working practices (Latham, 1994; Egan, 1998; Egan, 2002; ROADCON, 2002 and 2003; Constructing Excellence, 2003). Traditional working practices and lack of standardised procedures has resulted in fragmentation within the industry and disjointed project teams (Latham, 1994; Egan, 1998; Egan, 2002). Each discipline, based on their involvement in the project life-cycle, has adopted processes which suits their needs. Sir Egan has highlighted the problem of disjointed project teams and bespoke processes in his report, Rethinking Construction (1998) and had demanded the industry to change its traditional processes to a more integrated ways of project delivery.

Prior to the introduction of the Personal Computer (PC), traditional working practices defined as the lowest level of maturity in 4C's maturity model, were heavily paper-based centric, which was a barrier to coordinated and up to date project information. The archival and maintenance of paper-based documents was managed manually which meant information was not accessible when required. With the uptake of the internet, the industry moved to electronic documents as well as means of managing them and traditional methods were replaced by Computer Aided Design (CAD) and the use of e-mail (Neff *et al.*,2010; Perumal and Abu-Bakar, 2011). However, CAD which was supposed to be a computer design tool to increase the quality of design and improve the management and communication of drawings through better documentation was utilised as an electronic drawing board to produce drawings in document formats. The resulting documents were exchanged via e-mail, which meant information was unmanaged and still exchanged in an ad-hoc manner. E-mail had been established as a formal communication channel, in accordance with 4C's correspondence maturity level, and verbal communications were no longer accepted unless they were recorded by e-mail (Dissock and Neff, 2011).

With the emergent of Web 2.0 technologies and the demand from the industry for a more centralised repository for sharing and managing project information, Electronic Document Management Systems (EDMS) or so called Extranets became popular. After a while EDMS were integrated with e-mail systems to move the industry to the coordination maturity level of 4C's maturity model, and to automate the workflows and notify project participants of outstanding tasks and activities which resulted in large number of e-mail (some unimportant and unnecessary) getting distributed.

The traditional means of information exchange in construction utilises manually created 2D drawings, which are geometric shapes but with no built-in intelligence (apart from a limited set of metadata concerning the document itself), and exchange them from initial stage of design to client approval, construction and facilities management. The pilot study revealed that one of the main reasons for the complex working environment in construction is that there is no single platform for project delivery. Projects have implemented different platforms to optimise different work processes and manage projects' information, which are on extranets, e-mail, FTP links and some on participants' desktops.

Based on the findings from the pilot study, section 5.1, the key five ways of exchanging information are as illustrated in Figure 36:

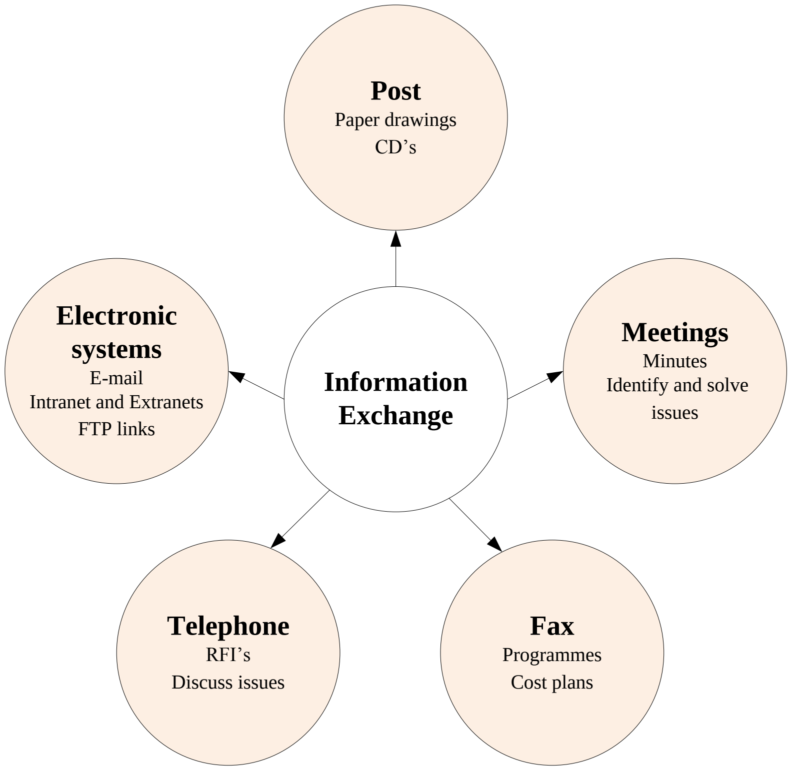


Figure 36: Traditional methods of Information Exchange within Construction Projects

Results from the pilot study and the data mining also demonstrate that professionals in the industry consider their activities as exchanging information in a document form in various formats; doc. xsl. dwg. Or pdf. In construction a 'document' is an immutable published output that is not intended to be re-used other than in its original physical form. It is any kind of piece of information which is manifested in one or more information containers; file, printed report or e-mail.

According to Hill (1995) the use of e-mail has become inevitable. Almost in all construction organisations, e-mail has been established as both formal and informal communication channel with no rigorous audit trail or a pre-defined strategy. Hence, each organisation has established an e-mail policy which is different to the rest of the industry. In some cases, there are no e-mail policies and individuals are left to manage their inboxes based on their personal preference. E-mail was designed as a communication tool but instead it has been utilised as a 'records' and 'task' management system. On project level, e-mail has also been utilised for exchanging project information with no prior communication protocol or agreement in relation to meta-data, management, audit trail and archival. Reliance on e-mail without a standardised strategy and defined protocols, dependence on individuals' professional judgement, poor e-mail management, poor audit trail and treating e-mail as tasks rather than a means of communication has resulted in e-mail overload, information duplication, information and in some cases knowledge loss (context), reduced awareness as well as a challenging task of archiving e-mail which would affect an organisation's productivity (Whittaker and Sidner, 1996). Establishment of an e-mail policy with rigorous e-mail management procedures would improve e-mail management, archival and audit trail.

The use of e-mail promotes the exchange of documents as attachments. However, BIM is introducing new ways of working in which the industry should move away from a document-based centric environment to a more data-driven environment using intelligent and data rich information models and integrated processes. Building Information Modelling at its highest level of maturity requires a set of integrated and consistent processes with a single and fully integrated 3D information model with real-time access to information about all physical and functional characteristics of an asset or a building built-in to the model as attribute data. It also requires an Integrated Project Delivery (IPD) approach, which means there must be a collaborative framework, i.e. 4C's collaboration maturity characteristics, in place for all contracted parties to work collaboratively on the data embedded in the information model. Although e-mail is free to use and is believed to be the fastest way to communicate information, it has technological limitations to be utilised as a means of communicating real-time data and 3D information models. Utilising technologies such as Web 3.0 and web semantics will enable participants to work simultaneously on an information model without the need to extract the data in a document or drawings format.

The MacLeamy curve, Figure 37 illustrates a comparison between traditional processes (black curve) and preferred processes (blue curve) introduced by BIM.

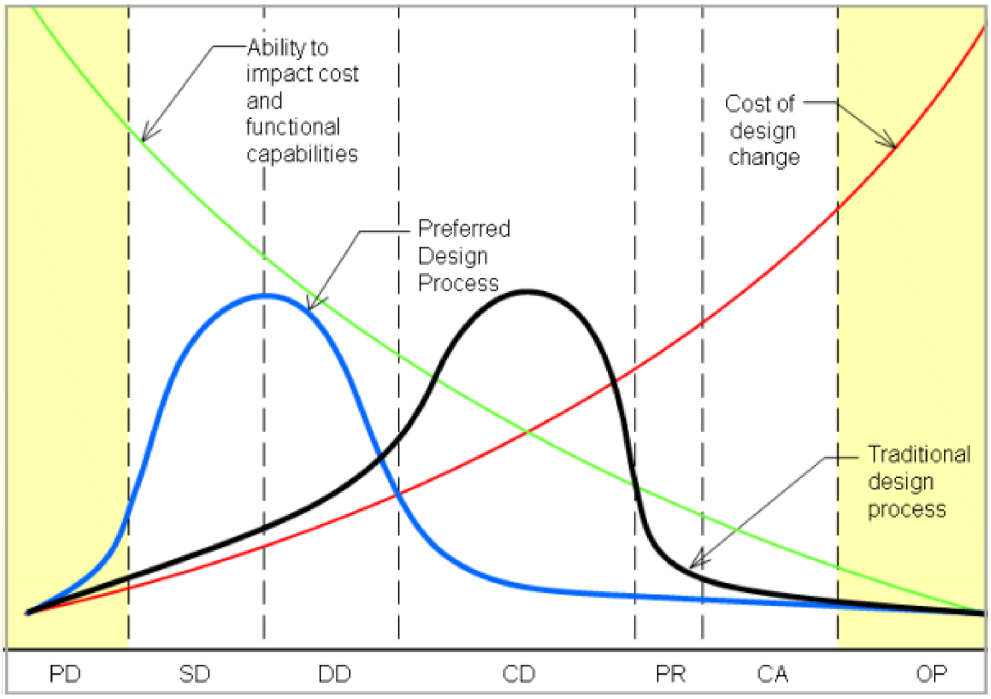


Figure 37 – MacLeamy Curve – Taken from buildingSMART

The X axis determines the RIBA plan of work (i.e. common project stages) and the Y axis demonstrates the amount of effort required at every project stage. The purpose of the MacLeamy curve was to illustrate that the more developed a project gets (i.e. during detailed design and construction), the more difficult it becomes to make changes. More difficult in this context means greater amount of effort required, less functional capabilities and more cost implications. More effort in this context is understood to be any extra activity including information exchanges that needs to be undertaken to make the necessary changes.

MacLeamy curve suggests that the implementation of BIM should result in less re-work and less information exchanges during detailed design and construction. However, the results of the statistical analysis of this research, section 6.1.4.4, are in contrary with his suggestions. The results show that the distribution of information is not normal and the patterns of information exchange and document creation for BIM and non-BIM projects are both similar and variant. For the purpose of this research BIM projects have been defined as projects that have utilised 3D information models and have exchanged native files for coordination, simulation and analysis purposes and non-BIM projects have been defined as those projects with no use of 3D information models. Native file means the original Graphical and/ or Non-graphical data file in its default format, created in the authoring tool.

More than 50% of the BIM projects have high peak values of information exchange and document creation later in the project life-cycle (i.e. detailed design and construction).

Equally, a third of the non-BIM projects have high peak values of information exchanges during feasibility and concept design stages. Similarity in patterns of BIM and non-BIM projects means, although BIM introduces intelligent information models, centralised repositories and advanced information management techniques, the amount of effort required to produce and exchange electronic information (i.e. electronic communication) has not decreased nor pushed back to earlier project stages.

Findings from the pilot study and focus groups (sections 5.2 and 5.4) also show that, the industry is still applying the traditional methods of working, which had been developed around documents, to the new concept of BIM. Findings also show that, across the industry, there are clear lack of understanding of collaboration and information requirements, upfront planning and defining communication protocols, processes and systems prior to project start. In addition, existing procurement strategies and contractual agreements do not have the right legal backdrop to allow early engagement between the client and the supply chain. Lack of early engagement is an important factor when in planning and defining and agreeing communication protocols. These reasons are the contributing factors to the increase in electronic communication and barriers for the industry to move up to the next levels of the 4C's maturity model. The issue is that the industry's main focus has been on the use of digital engineering before establishing appropriate collaborative processes and ensuring minim information required to support this process as well as ways in which this information is communicated is identified, captured and communicated contractually. Once these processes are defined and established, then data visualisation, simulation, analysis and mobility can be utilised to exploit data to its maximum potential.

The industry has been persistent in communicating information in information intense environments using unreliable communication technologies (Crotty, 2012). As the industry adapts to the paradigm shift of a more data-driven culture, new frameworks for the production, management and delivery of information emerge. One of these frameworks, which was developed on a very similar concept to the CSCW is the Common Data Environment. As previously explained in section 3.3.3, the CDE, pioneered through the early 90's, is a process that enables the exchange of information through the use of collaborative tools to eliminate wasteful activities such as duplication and re-work (PAS1192-2, 2013). However, the CDE is very much process focused and was designed to accommodate the management activities around documents and relies on the exchange of information in the form of documents and drawings, i.e. static records. Neff *et al.* (2010) suggests that 'boundary-spinning' collaborative tools should include the study of technology and should be designed in such way that the multiplex interactions that exist across organisations can be managed and maintained. Clark and Brennan (1991) in agreement with Neff *et al*. argued that CSCW, which is a sub-field of Human Computer

Interaction, should include the study and development of technology to support the dispersed project teams to communicate more effectively with less amount of effort required.

Today, on typical multi-disciplinary projects the communication networks will inevitably involve discipline specific information models and a multitude of software platforms and file transfer become an issue, even if file transfer protocols (such as IFC) are agreed upfront. Although there has been great efforts made on interoperability and Industry Foundation Classes (IFC) by buildingSMART, the quality of IFC extraction remains to be an issue. Prior agreement on the use of classification systems and the ways in which the information models are structured is also another important problem facing the industry. It is believed that the BIM Toolkit, recently launched by the National Building Specification, will provide a common classification system for the industry (both buildings and infrastructure). The BIM Toolkit is a free to use, online toolkit which offers a digital plan of work (i.e. project stages in a digital format) and introduces a new unified classification system. The digital plan of work highlights the issues surrounding the level of detail. These should provide reference material that could be used to help set clear requirements for how IFC should be structured and in validating compliance at different project stages.

7.2 BIM Technologies

The purpose of this section is to discuss the following research question:

- Are electronic communication systems (i.e. extranets) currently used, scalable enough in terms of technology and people, to meet the future increase in communication brought about by BIM?

Project Information Models comprise of three key component parts, as illustrated in Figure 38 Graphical data (representing the physical characteristics of an asset, typically a 3D format), Non-graphical (representing the functional characteristics of an asset, typically an excel spread sheet) and Documentation (outputs comprising of views of the Graphical data and Non-graphical data, typically in PDF format), all of which need to be aligned and cross-referenced (BS1192, 2007).

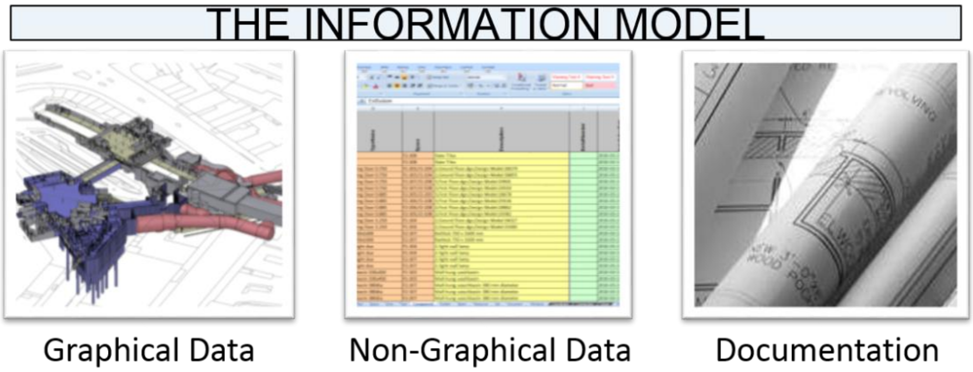


Figure 38: Component parts of information models

Despite existing electronic communication systems having the functional capabilities to support the re-use and spatial coordination of 3D information models, technological and contractual limitations do not allow for different discipline-based 3D information models to be produced and managed in a single environment. Therefore, the outputs from information models, usually in a 2D drawing or a 3D PDF format, are used for information sharing. This argument is confirmed by the results from the statistical analysis of this research, where EDMS are utilised to share information model outputs and in some cases federate information models. Also, although inconsistencies in the ways in which information is produced and managed (i.e. inconsistent file naming, suitability, meta-data and data structures) make it more difficult to find the right information at the right time, all focus groups participants agreed that the existing electronic communication systems are capable of managing the Non-graphical, Documentation and outputs from Graphical data.

When BIM, as a technology, is utilised in accordance with 4C's maturity model (Figure 39) the levels and outcomes (exchange media) would be specific to the applications of BIM and would be recognised by the industry as the following 4 ways of implementing BIM:

1. Autonomous BIM
2. Document Managed BIM
3. Federated BIM
4. Unified BIM

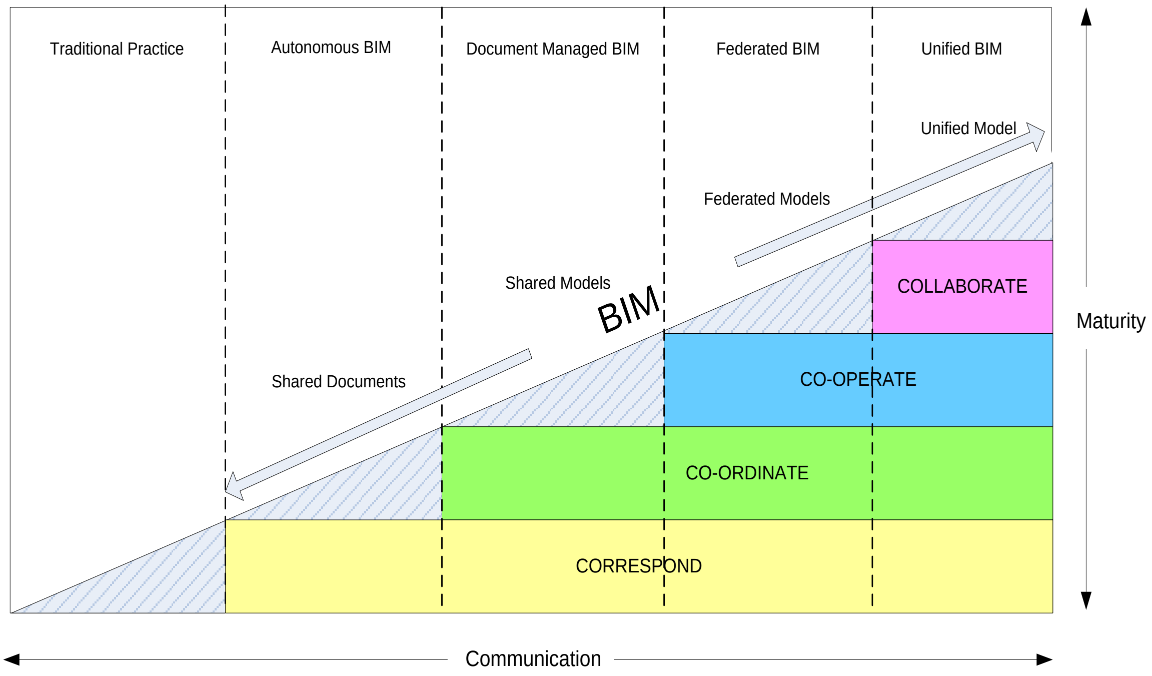


Figure 39 : Project Communication Maturity Model utilising BIM

In order to understand how to assess the capability at each level there are minimum requirements and characteristics that are expected to occur at each level. For a project to operate at the level of Autonomous BIM, it must employ an object-based modelling tool to create, extract and send ‘documents’ using technologies such as e-mail. These documents are only used for transmittal and will be unsolicited, unreliable and unmanaged. The use of Autonomous BIM has no contractual implications and is consequentially insignificant.

Similarly, for a project to be considered at Unified BIM level, it must include unified culture, processes, technologies and policies. As an example, sharing information via model servers or cloud computing through pre-defined contractual agreements which clearly states all parties are to share information, risk, liability and trust via unified workflows and full integration.

However, as the industry continues its transition to a more data-driven environment, utilising advanced digital design and engineering methodologies, the need for exchanging information model files and digital reporting, querying and archiving large data-sets (i.e. COBie) will increase. As a result data validation and verification becomes extremely important to ensure consistency within the industry as to how data and information is structured and managed to the same form and quality so that it can be reused without change or interpretation. Therefore, there is a need for more advanced communication systems with high performing servers (such as Apache Cassandra server) to replace existing EDMS to perform verification and validation checks on model files and large amounts of data. Validated data could avoid any potential litigation problems and would allow for native model files to be contractually accepted.

Contractual limitations and lack of clarity around roles and responsibilities in relation to data authoring and production, intellectual property rights, ownership, liability and obligations were other dominant issues raised during the focus group sessions. These were mainly applicable to the creation and exchange of 3D information models with embedded component parts and object libraries. Focus groups participants strongly believed that the roles and responsibilities matrix must be defined and cascaded down the supply chain at early stages of the project. At the time, BS1192:2007 was the only standard with clear guidance on roles and responsibilities, however, these roles were around the production, management and delivery of the outputs of Graphical data, Non-graphical data and Documentation and not around the native model files exchange. Since then, the publication of the CIC BIM Protocol, as a standard contractual arrangement, has provided further clarity with regards to the following points:

- Roles and responsibilities for the data and information – what is each project participant required to produce and what (if any) constraints are imposed on them
- Management of the data and information – how is the data to be managed and what are each parties responsibilities
- Errors, emissions and defects – what are the liabilities of each party relating to the data that is shared across the various project participants

7.3 People and Culture Change

The purpose of this section is to discuss the following research question:

- Is BIM an effective enabler for collaboration and reduced electronic communication?

The Government's Construction Strategy published in 2011, and further updated in 2016, identifies BIM as one of the core components, which will '*derive significant improvements in cost and value through the use of open sharable asset information*'. And as a result, the Government requires a '*fully collaborative production of all project and asset information in electronic format*' on all centrally procured projects from April 2016. To achieve this target a set of industry standards, as well as enabling technologies, have been introduced to establish a consistent approach to BIM implementation across the industry.

Figure 40 has been adapted from Bew and Richard's wedge diagram, to demonstrate the different BIM Maturity levels as well as supporting standards required for each level of maturity.

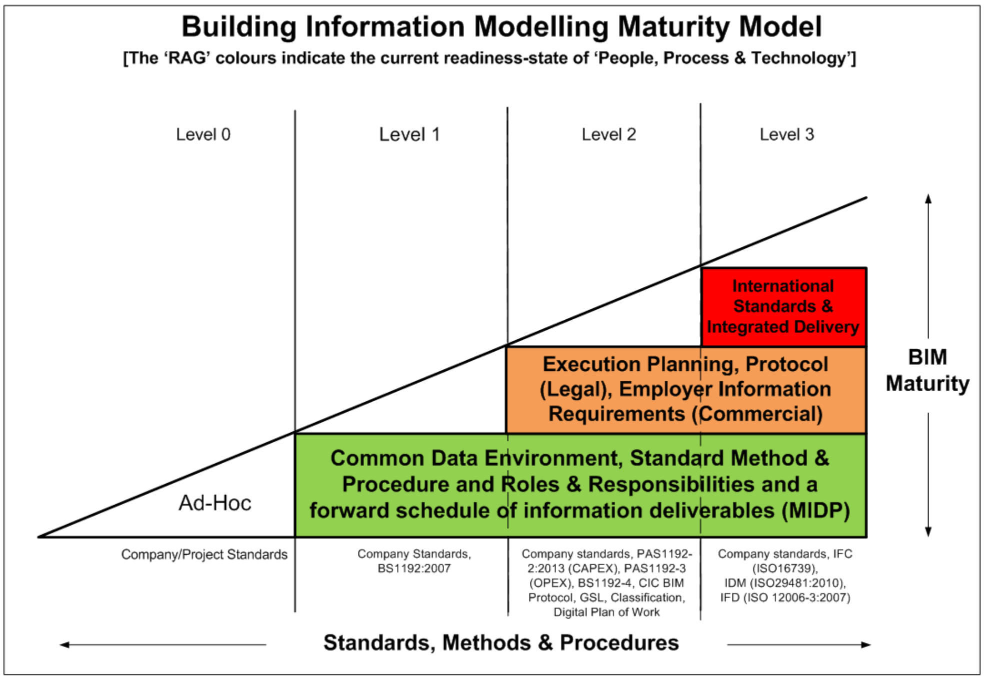


Figure 40: Adapted BIM Maturity Model (Bew and Richard's Wedge Diagram 2010)

As discussed in section 2.8, level 0 BIM is unmanaged 2D CAD data as well as paper-based documents. Level 1 BIM establishes the foundations to all levels of BIM maturity. It requires a standardised digital approach to the production, management and delivery of all project information based around BS1192:2007. The output of level 1 maturity includes coordinated 2D information and may include 3D information models with some spatial coordination. As demonstrated in Figure 40, a Common Data Environment, a Standard Method and Procedure and a Master Information Delivery Plan (MIDP) are key component parts of BS1192:2007 and required for a Level 1 BIM capable project. As described in section 3.3.3, a CDE is a set of defined processes used to exchange and manage all project information. The Standard Method & Procedure provides a consistent approach to the production, management and delivery of all project information, including file naming conventions, suitability code, meta-data and roles and responsibilities. The Master Information Delivery Plan is a forward looking schedule of information to be delivered, by the project teams, at each project milestone; identifying who is responsible for the preparation of the information, when it is to be delivered, to what level of maturity and its revision and suitability.

Level 2 maturity builds on the foundations of BIM Maturity Level 1. At Level 2, there is greater emphasis on consistently capturing and articulating information requirements to support the whole lifecycle management of assets. There are also greater legal and commercial influences in relation to the production, management and delivery of project and asset information. The output of level 2 includes discipline-based 3D information models, which will be assembled to form a fully coordinated federated model.

The BIM Task Group's foresight to enable Level 3 maturity is reported on in the Digital Built Britain initiative. At Level 3 BIM, it is anticipated for concepts such as Big Data, Internet of Things and Smart Cities alongside the ever more sophisticated technologies to benefit from exploiting joined-up data and information. The output of level 3 may include a single, open and fully integrated 3D information model with real-time access to data via the utilisation of web services and open standards.

It is ever more important to have consistency within the industry as to how project information is structured, produced, exchanged and managed, to the same form and quality, so that information can be reused without change or interpretation. Although standards and protocols developed for BIM Level 1 and 2 are document focused and not appropriate for utilisation of an integrated and optimal BIM environment, they have been a significant step towards creating consistency and standardisation across the industry, which are pre-requisites of collaboration, which according to the 4C's model is the most mature form of communication with the least amount of information exchanges required.

With unprecedented volumes of information being produced today and the emerging use of BIM, the industry is moving towards a centralised repository with information rich models, which will enable the Construction Industry to respond to the drive towards Big Data and Smart Cities. Although the statistical analysis demonstrates that there are no differences between BIM and non-BIM project patterns, the intelligence of information models, centralised repositories and advanced information management techniques will alter the existing communication mechanisms and reduce the amount of communication required. The issue is that the industry's focus has been on the use of digital engineering before establishing appropriate collaborative processes and ensuring minim information required to support this process is identified, captured and communicated contractually. Once the process is defined and established, then data visualisation, simulation, analysis and mobility can be utilised to exploit data to its maximum potential. The industry needs to recognise that BIM comprises of two key components, as illustrated in Figure 41; Information Management and Digital Engineering.

- Information Management - a set of Standards, Methods & Procedures to provide a consistent collaborative approach to the production, management and delivery of project and asset information
- Digital Engineering – the capture and exploitation of digital data to support data analysis, visualisation and reporting. Examples of Digital Engineering may include the application of Virtual Design (3D), Virtual Scheduling (4D), Virtual Estimating (5D), Virtual Carbon Management (6D), Virtual Whole Life-cycle Management (7D), digital fabrication and the use of mobile technology.

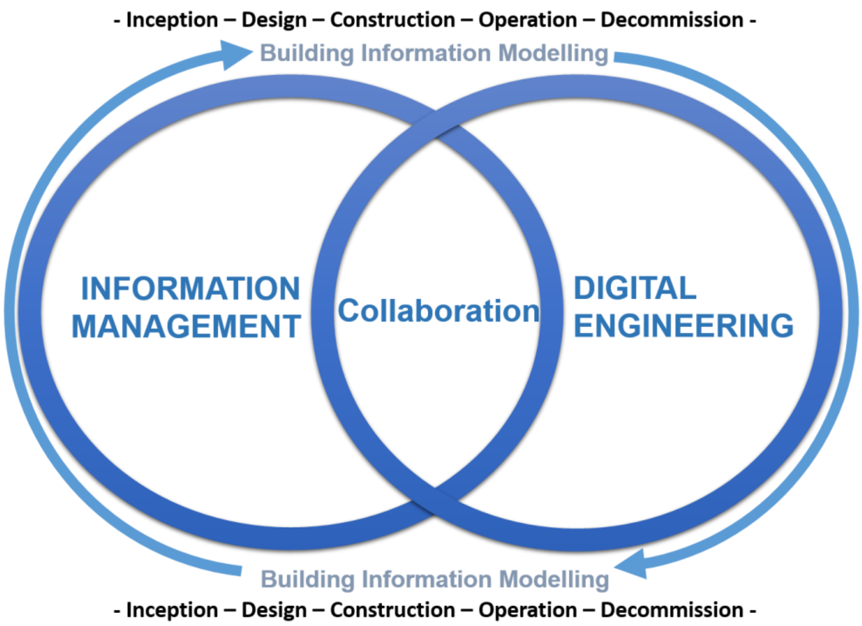


Figure 41: BIM components

Figure 41 illustrates the importance of both Digital Engineering (technology) and Information Management (process) and the fact that they go hand in hand. However, BIM is reliant on people's behaviour and their ability to work in collaborative environments. It is people following the agreed processes and using the appropriate tools and systems that will result in collaboration. Thus, collaboration is a by-product of Technology, Process and People. People is a key aspect of BIM, which is missing from Succar's interlocking BIM activities Venn diagram, as demonstrated in section 2.7. More emphasis on the People aspect of BIM is required, because effective implementation of BIM requires significant changes in the working practices and the industry's culture (Arayici *et al.*, 2010).

Some of the key cultural barriers identified during the course of this research study, which are real blockers to an effective collaboration and reduction in communication are as follow:

7.3.1 Digital Engineering Capability/Competency

Many BIM and architectural technologists, specialising in the applications of technology have entered the world of Construction with the intention of helping principal architects and senior engineers to build assets virtually prior to physical construction. However, most of these graduates have limited knowledge of the engineering behind adequate design and construction. Lack of engineering knowledge usually results in inadequate, incorrect and low quality information being distributed. This issue needs to be approached from schools and universities as well as upskilling across the industry.

7.3.2 Cost Driven Culture

The Construction Industry has always been cost-driven, aiming for delivering projects on predefined budgets without focusing too much on the quality and long term values. Because of this, the culture of 'blame' is widely accepted and professionals within the industry use electronic communication systems as a means of recording conversations and an audit trail for decision making. One of the pilot study participants described this as a 'get out of jail' culture whereby people are expected to "*make decisions that could actually cost in the long run could be millions of ponds. And even though someone knows that they still send an email and think they have done their job*".

A 'no-blame' culture requires transparency and trust so that project participants could be protected from being blamed for failure. Building Information Modelling could not build trust between different organisations, neither could it change the existing culture of 'blame' within the industry. Strong leadership is required to change the 'no-blame' culture by promoting a value-driven approach and collaboration, which is closely linked to behavioural drivers.

7.3.3 Document Management to Data Management

With the emergent uptake of BIM, the traditional working practices, which are document centric need to change to data-driven working practices. The industry needs to treat its information as an asset and become more aware of the benefits of a more dynamic environment with access to structured and up to date data (McLeod and Hare, 2010). Data utilised to produce documents is locked in the documents as static records. The document management approach has led to disconnected data sets. As the industry continues its transition to a more data-driven environment, utilising advanced digital design and engineering methodologies, the need for exchanging model files and reporting, querying and archiving large data-sets (i.e. COBie) will increase. In response to this increase, a paradigm shift is required to move to more advanced communication systems with high performing servers to replace existing document management systems.

7.3.4 Legal and Commercial Contractual Arrangements

Hesitation about adopting collaboration platforms such as BIM, has always been due to concerns around electronic information exchange obligations and liabilities. In addition, to respond to the move towards data-driven environments with access to real-time data, existing contractual documents need to change to suit the needs of a more data-driven environment.

Although it is claimed that little change is required in the fundamental principles of contracts, existing contractual arrangements including NEC3, JCT and CIOB Complex Project Contracts require essential investments to define data-driven responsibilities, ownership rights, copyright laws, ways of working and desired outputs to promote collaboration. Guidance emerged by the Construction Industry Council (CIC) has addressed these issues and has established a suitable legal and contractual framework for existing contracts to govern the use of BIM.

7.3.5 Collaborative Frameworks

Although in practice BIM links up project participants more closely in terms of processes and governance, they remain organisationally divided, which often results in timely access to crucial information for decision making (Dossick and Neff, 2010). For a successful uptake of collaboration, the industry needs to take a broader approach to the concept and incorporate commercial notions such as partnering, alliancing and the use of standards such as BS11000 for long term relationship management, alongside BIM. It’s key to remember that BIM is only an enabler for collaborative working.

Partnering and alliancing are believed to promote collaborative working but rely heavily on trust, pain/gain and mutual faith spirits. However, currently, relationships within the industry are established based on projects’ short-term outcomes, which are often cost focused. Collaboration platforms such as BIM are starting to introduce new ways of working which are based on long-term relationships so that all project stakeholders take an interest in the whole life-cycle of a project.

7.3.6 Education, Training, Accreditation/Certification and Support

There are varying degrees of BIM adoption within the industry, which has resulted in a recognised skills gap, requiring up-skilling to meet the Government’s BIM mandate. Butler Group (2003) believes that people is the most important element and usually the most difficult to change. Therefore, education and training is essential to alter the perception of isolated attitude to a more collaborative notion.

There is a lot of demand to receive more support and guidance from the BIM Task Group and the well-established professional institutions, including RICS, CIOB and ICE. However, the concept of BIM covers a wide range of theoretical groundings and could be interpreted differently by organisations and individuals, based on their expertise and positioning within the project and asset life-cycle, therefore it cannot be taught in one course.

The BIM Task Group's initiative to develop the Learning Outcome Framework has motivated the professional institutions such as RICS and buildingSMART to put in place training and accreditation courses to encourage the industry to come to a common understanding. Also, several universities are now offering BIM master degrees; however, the presence of BIM in undergraduate and college courses is still very limited.

As the industry moves towards more data-driven environments, there is a need for other professions including data scientists, computer scientists, data analyst, psychologists and information managers to enter the Construction Industry. The industry is already seeing some of this, Behaviour4Collaboration group is one of the many BIM4 groups developed by the Government's BIM Task Group to bring in specialists from both within and outside Construction (both academia and practitioners) to study and promote the right collaborative behaviours and to capture and apply lessons learnt from other industries (such as car and manufacturing) on how they approached partnering.

7.3.7 Leadership and Digital Construction

Although BIM has been promoted as a paradigm shift and a rigorous solution to collaboration challenges within the industry, it has been observed that organisations are still facing challenges that limit collaboration. To overcome these issues people rely on individual leadership to inspire collaboration. There is a clear need to close the gap between the old generation, which are used to traditional and paper-based ways of working and young generation, which have been brought up with social media and online gaming. The industry needs more young leaders with aspirations to be proactive in leading drive the data-driven environment, big data and smart city agenda.

CHAPTER 8 - CONCLUSION

This research study set out to explore the impacts of BIM on communication patterns of Construction projects and has identified some of the issues with complex and temporary project networks, as well as the issues surrounding communication and collaboration. These issues are due to the growth of the industry in relation to technology, organisation size, project complexity, cultural changes and innovation (Chapter 7).

There are opposing views within the industry with regards to the impact of BIM on communication patterns within construction projects. These views are polarised into the belief from one extreme, BIM will lead to improved communication and from the other that BIM will lead to increased unmanaged and unreliable information exchanges during the design and construction processes of projects. Therefore, this study sought to compare the difference in opinion and examine a wide range of concerns around communication practices by answering the following research questions:

- How will the implementation of discipline-based information models and the use of traditional working practices impact electronic communication?
- Is e-mail an effective means of communication for BIM enabled construction projects?
- Are existing electronic communication systems (i.e. extranets) capable of meeting the communication needs brought about by BIM?
- Is BIM an effective enabler for collaboration and improved electronic communication?

The research questions were answered through utilising a mixed method strategy with a combination of qualitative and quantitative methods and the empirical findings were categorised within the respective chapters (Chapter 5 and Chapter 6). The qualitative methods, including pilot study and focus groups, allowed to gain an insight into professionals' experiences using existing communication technologies, including e-mail, and following the traditional communication processes. The pilot study provided clarity on what communication channels are currently utilised, how they are configured, managed and in some cases integrated with other collaborative systems. Following the pilot study, the focus groups illustrated an overarching picture of existing BIM practices. The results of the focus groups together with the pilot study allowed to gain an understanding of how the existing communication patterns may change with the adoption of BIM and resulted in formulating a hypothesis. The hypothesis was then tested, using quantitative methods including statistical analysis and data mining. Answers to research questions have been extracted from the findings of both stages of the research.

This section will synthesise the findings in order to answer the four research questions.

1. Will the implementation of discipline-based information models and the use of traditional working practices increase electronic communication? While the UK Government continues to encourage the Construction industry to move from a manual and document-based industry to one which exploits advanced digital design and engineering techniques, the professionals within the industry are still bound to traditional and inconsistent working practices (Latham, 1994; Egan, 1998; Egan, 2002). The traditional working practices include complex working environments with no single communication platform and no integrated process for information sharing. Projects have implemented different communication platforms with bespoke communication processes to manage project information, which are currently mostly document based and are exchanged via e-mail, extranets, FTP links and in some cases, memory sticks, file sharing and CDs. Manual processes and lack of standardised procedures have resulted in information being produced, used and managed in a disjointed manner across the industry (Latham, 1994; Egan, 1998; Egan, 2002; ROADCON, 2002 and 2003; Constructing Excellence, 2003; Akintoye and Main, 2007; BSi, 2010; Son and Rojas, 2011; Ballan and El-Diraby, 2011). However, BIM introduces new ways of working through a new set of technologies which utilise object-based and data rich information models for advanced information management. This way of working is heavily data driven and requires a standardised way of producing, using and managing information, which are spatially enhanced and support a more collaborative environment. Almost all participants interviewed during the pilot study and those who took part in the focus groups, agreed that there are 3 key areas to tackle to avoid the increase in communication using discipline-based information models;

a) Technology: the use of discipline specific information models is challenging as different disciplines use different software platforms, therefore interoperability and file transfer become an issue.

b) Process: BIM endorses collaboration and more integrated processes. However, the industry is still bound to traditional and disjointed ways of working.

c) People: New ways of working always require people to change and adapt to the new environment, which requires a change in culture.

A change in culture will require the most effort and will need to be embraced by the majority of the industry to have a positive impact. Without careful consideration of Technology, Process and People, which are the key enablers of BIM implementation, the industry will face an increase in electronic communication, i.e. the exchange of electronic information. Also, it is clear from the statistical results (section 6.1) that the distribution of information is not normal and the patterns of information exchange and document creation for BIM and non-BIM projects are both similar and variant. Similarity in patterns of BIM and non-BIM projects means the increase in electronic communication is not due to the implementation of discipline-based information models but the lack of understanding of information requirements, upfront planning and defining communication protocols, processes and systems prior to project start. In addition, existing procurement strategies and contractual agreements do not have the right legal backdrop to allow early engagement between the client and the supply chain. Lack of early engagement is an important factor when in planning and defining and agreeing communication protocols.

2. Is e-mail an effective means of communication for BIM enabled construction projects? All participants from both the pilot study and the focus groups suggested that e-mail has become the main communication channel in both small and large firms and for both formal and informal communication processes. Although the general feeling was that e-mail is not the right tool for communicating project information (in particular model files and large drawing files), they feel it is the fastest and easiest tool to use. All participants agreed that they are overloaded with the amount of information coming through via e-mail. The overload is due to the reliance on traditional working practices, lack of standardised procedures and the exchange of project information, typically in a PDF or drawing form as an attachment, with no prior agreement on project level in relation to meta-data. The results from the statistical analysis illustrate the lack of upfront assessing and clearly defining communication protocols, processes and systems, which in turn has resulted in an increase in electronic communication. Unless e-mail is defined as an appropriate tool for communicating project information as part of the communication protocol, the utilisation of it will result in information exchanges which are outside of defined and managed process, which in turn will result in information duplication, overload and errors. It is evident from the pilot study and focus groups results that e-mail has not been a wholly effective communication tool even without the utilisation of BIM and based on the findings of this research, the implementation of Autonomous BIM will make e-mail users more overloaded than before due to the fact that BIM makes the production and extraction of electronic drawings/documents much easier. BIM is believed to be a driver to move the industry from static documents to a more data-driven environment utilising data-sets, data schemas and data bases. Therefore, it is likely that e-mail will not be the most effective media for communicating project information in the future.

3. Are electronic communication systems (i.e. extranets) currently used, scalable enough in terms of technology and people, to meet the future increase in communication brought

about by BIM? Due to technological and contractual limitations, as highlighted in Chapter 7, currently the outputs from Information Models (i.e. PDF and Drawings) are used for sharing information via existing communication systems (i.e. extranets). Although inconsistencies in the production and management of these documents (i.e. inconsistent file naming, suitability, meta-data and data structures) make it more difficult to find the right information at the right time, all participants agreed that the existing communication systems are capable of managing these documents. This argument is confirmed by the results from the statistical analysis where EDMS are utilised to share information model outputs and in some cases federate information models. However, as the industry continues its transition to a more data-driven environment, utilising advanced digital design and engineering methodologies, the need for exchanging model files and reporting, querying and archiving large data-sets (i.e. COBie) will increase. As a result data validation and verification becomes extremely important to ensure consistency within the industry as to how data is structured and managed to the same form and quality so that it can be reused without change or interpretation. Therefore, there is a need for more advanced communication systems with high performing servers to replace existing EDMS to perform verification and validation checks on model files and large amounts of data. Validated data could avoid any potential litigation problems and would allow for native model files to be contractually accepted.

4. Is BIM an effective enabler for collaboration and reduced electronic communication? Currently, majority of project participants correspond with one another in an unmanaged and unreliable (so called ad-hoc) way, mainly by e-mail. Just because project members are working together to get the project completed on time does not make them collaborators. They may well be coordinating through managed and structured sharing of documents via transmittals, aligning activities and schedules, as well as managing dependencies using extranets with assigned roles and responsibilities, agreed workflows and data structures, or in some cases, cooperating at a higher level than just regarding a project, which requires interaction and commitment between organisations with more structured information.

With unprecedented volumes of information being produced today and the emerging use of BIM, the industry is moving towards a centralised repository with information rich models, which will enable the Construction industry to respond to the drive towards Big Data and Smart Cities. Although Chapter 6 section 6.1.4.4 demonstrates that the patterns of information exchange and document creation for BIM and non-BIM projects are both similar and variant; the intelligence of information models, centralised repositories and advanced information management techniques will alter the existing communication mechanisms and reduce the amount of communication required. The issue is that the industry’s focus has been on the use of digital engineering before establishing appropriate collaborative processes and ensuring minim information required to support this process is identified, captured and communicated contractually. Once the process is defined and established, then data visualisation, simulation, analysis and mobility can be utilised to exploit data to its maximum potential.

BIM also promotes instinctive but rigorous collaboration by requiring multi-disciplinary teams involved in a project to have predefined communication protocols with full workflow integration (Integrated Project Delivery methods for instance), shared resources, risk and liability, a high level of communication and a real-time pipeline to interact with a virtual environment. However, BIM will not build trust between different organisations, neither will it change the existing culture of file-based information sharing within the industry. Culture requires leadership and project participants who believe in the change. The right culture will result in the right attitude and trust between project professionals. BIM is only an enabler for collaborative working; the pillars of collaboration must exist within an organisation, with or without BIM.

The existing literature suggests that there has been no specific research in evaluating and systematically defining communication as a form of interaction around BIM models or electronic communication patterns in general within construction project teams. One of the reasons for incorrect perceptions and the usage of electronic communication is the lack of research undertaken in this field. Another reason is that the uptake of BIM within the industry is partial and fragmented and therefore, there is little evidence of what the real benefits of BIM may be. Lack of conceptual understanding of communication patterns has limited the knowledge required to develop a theoretical framework for implementation of a successful collaborative environment. Although literature suggests that BIM frameworks are being developed by researchers and BIM models are promising integration, interoperability, improvement in web-based collaboration and communication, there is no concrete evidence within the industry. Chapter 7 demonstrates that organisations are still facing challenges that limit the realisation of BIM benefits to their full potential.

Implementation and adoption of a Unified BIM for interdisciplinary collaboration requires an understanding of the communication maturity and project specific contingencies within individual organisations. BIMAEC (2012) states that; “*if our communication skills were poor before BIM, then BIM only serves to enhance our disability*”. BIM must be employed not only as a set of consistent processes, but also as a tool to improve communication protocols. The Construction industry has yet to appreciate the fundamental benefits of third generation collaborative technologies. These technologies have the potential to reshape the organisational structure of organisations and alter the roles and responsibilities of employees.

8.1 Original Contribution to Knowledge

The BIM Maturity Model developed by Bew and Richards (2010) and discussed in section 2.9 does not provide a conceptual framework to examine the current working processes and modify them if needed. What it demonstrates is a framework to investigate BIM without highlighting the fundamental underlying processes and how these processes should be modified to improve collaborative working. Therefore, there is a need for an organisational framework which would provide a high level insight into the communication patterns of construction projects in order to demonstrate the capability of projects at different levels. There have been efforts, both within Construction and other sectors, to develop such maturity models. However, the focus of most studies within the Rail and Construction sectors has been from a project viewpoint and not an organisational level. For instance, Badiru (2007) investigated communication, coordination and cooperation and developed a triangle for more effective project management.

To date, and as far as this research is concerned, no other research has identified the impacts a new technology and a set of processes, for instance BIM, might have on existing and traditional communication patterns and the characteristics that are required for various maturity levels. Thahlheim (2011) undertook a study around collaboration and defined collaboration as communication, coordination and cooperation. In his study, he reviewed the work of other researchers to assist in concluding his framework. However, within the context of Rail and Construction industry and their fragmented environments, communication plays a key part in achieving a collaborative environment. To this end, in this study, communication has been identified as the fundamental foundation, which needs to be in place before moving towards collaboration.

The outcome of this research project provides a conceptual overview of existing communication patterns within construction projects. In addition, it provides an original maturity framework for Communication, which will benefit all construction stakeholders who are assessing BIM adoption or are already in the process of implementing it. With the Government mandate on BIM Level 2 and the push to drive the industry towards a more data-driven environment, it is vital that professionals have access to established maturity frameworks, to ensure a consistent approach to implementation of BIM and a common language across the industry.

The framework will also provide the following benefits:

- It is a measurement tool for evaluating a project’s maturity with regards to communication.

- It will allow practitioners within the industry to develop more understanding of ‘softer’ aspects of Digital Engineering Systems integration and utilisation of ICT in general within construction projects.
- It provides a clearer framework for construction projects to be placed at different levels with regards to the identified characteristics.
- It provides guidance as to what capabilities should be offered at different levels in a federated working environment.

The study also presents findings from a mixed method strategy;

- Qualitative study (Chapter 5) - which illustrated that although BIM endorses more integrated processes, the professionals within the industry are still bound to traditional, disjointed and inconsistent working practices. The traditional working practices include complex working environments with no single communication platform and no integrated process for information sharing. E-mail has become the main communication channel in both small and large firms and for both formal and informal communication processes. E-mail users are overloaded with the amount of information coming through and with the implementation of Autonomous BIM, they will become even more overloaded. This is due to interoperability issues, together with bandwidth limitations for transferring model files. As a result, and because BIM makes the production and extraction of electronic drawings easy, professionals extract models as drawings and documents and communicate via e-mail. New ways of working always require people to upskill and change. This requires training, education and a cultural and behavioural change.
- Quantitative study (Chapter 6) – which demonstrated, through a data mining and statistical analysis exercise, electronic communication patterns and the relationship between project characteristics and the level of communication on construction projects. The results determine that the distribution of information is not normal and the patterns of information exchange and document creation for BIM and non-BIM projects are both similar and variant. Similarity in patterns of BIM and non-BIM projects means the increase in electronic communication is not due to the implementation of discipline-based information models but the lack of understanding of information requirements, upfront planning and defining communication protocols, processes and systems prior to project start.

The contributions of this study also include guidance for a new, multi-disciplinary and cross-industry approach and the fresh view the industry needs to adopt to achieve a collaborative environment through utilising BIM.

8.2 Limitations and opportunities for Future Work

This research study has demonstrated empirical findings on a significant and current development within the Construction Industry. The study encountered a number of limitations, which need to be considered;

- Researcher's bias – the results and outcome of the research may have been dissimilar if undertaken by someone with a construction background or any other background for that matter. A background in Computer and Information Sciences has been considered and used as a way of understanding and analysing all the problem areas and solutions throughout the research.
- Terminology – The term BIM means different to various industry professionals depending on where in the project life-cycle they are involved. Although the aim of the project is to cover the whole project life-cycle (design and construction), it is extremely difficult to capture all perspectives, who may be involved in a project, their thoughts and views, for instance, from client to designer to contractor and sub-contractors in the exploring and qualitative stage, as they all have different requirements and demands and it would be difficult to generalise the results.
- Pilot study sample size – because this study was undertaken early on and before the Government's mandate on BIM, people's understandings of BIM was restricted. Therefore, only a limited number of people with a good understanding of BIM were selected for the pilot study's interviews. Although the researcher feels that the pilot study was effective in better understanding construction processes and in identifying crucial experiences of the participants. However, if the study was undertaken today, the results may have been different. It may also have been a good idea to conduct an ethnographical design study for a more in-depth understanding of the problem area.
- Focus groups sample size – due to the lack of BIM experts in the industry at the time, it was difficult to fully grasp professionals' expectations of BIM and how an effective Information Model should be structured and exchanged.
- Inadequate Data-base Schema – due to confidentiality, most of the data extracted from the SaaS reporting system was anonymised. Also, due to the same reason, the SaaS company was unable to share all the information required to undertake a much more comprehensive analysis.
- Lack of prior research on this topic within construction - there was a lack of literature and any established metrics or variables affecting e-mail and communication around BIM at the time this research study started, which was also a barrier to comparing results from both stages of the study with other similar

studies. This research was initiated prior to the Government's mandate on BIM and should perhaps be repeated now that the BIM uptake is improved.

8.3 Recommendation for Future Research

BIM has been referred to by many within the industry as a 3D design tool and what is often reported about are the disadvantages of BIM in academia and journal papers. BIM in practice has offered solutions to the prevailing information management and collaboration issues and has provided the industry with standardised and consistent ways of producing, managing and delivering project and asset information that adds value throughout the whole life-cycle of an asset.

Since this research was initiated, there have been a lot of industry wide efforts to complete and publish the industry Standards for achieving BIM level 2 maturity. Building Information Modelling has been promoted widely as a framework and a tool that adds value throughout the whole life-cycle of a project; for instance, Total Expenditure throughout Capital Project Delivery and Operations and Maintenance. However, there still remains some underlying issues, which need to be resolved in order to obtain the most benefit from BIM as a collaboration platform.

Further research could be undertaken to investigate some of the key cultural barriers highlighted in section 7.3, including: digital engineering capability and competency, the cost-driven culture, the shift from document and records management to data and information management, legal and commercial aspects of project contracts, collaborative frameworks, education, training and support and leadership in digital construction. Identified barriers all play an important role in achieving a desired BIM capability.

More specifically, it has been observed that collaboration and communication requirements are defined by the project client. It is therefore recommended to utilise the 4C's maturity model in a client (either public or private) organisation environment to assess their communication maturity and identify the correlation between their maturity level and how well communication requirements, including communication protocols, processes and systems, are defined and contractually communicated on a project level. It is worth noting that, although there are subtle differences in the way in which public and private sector projects are governed, the foundations of project procurement is the same across all projects. If the client organisation is an operator and owner, the same method can be applied throughout the whole-life cycle of an asset to measure the impacts the maturity of communication has not only on how well the information is communicated during the project but also how well the information is handed-over, managed and maintained post project completion.

In addition, further research may be undertaken to investigate an appropriate approach to the implementation of the CDE, CSCW and 4C's maturity model on Construction projects. The study could investigate workflow integration, consistent structures for the production, exchange and delivery of project information as well as information validation, and explore the impacts contractual agreements would have on fostering such collaborative approaches. Northumbria's BIM Academy has initiated a research, under a TSB grant, called Tier2Tier based on a similar approach. The outcome of this research could further be developed to accommodate the notions of Big Data and Smart Cities to better understand how the CSCW theory and 4C's maturity model could provide solid foundations for information exchange governance across the Construction Industry.

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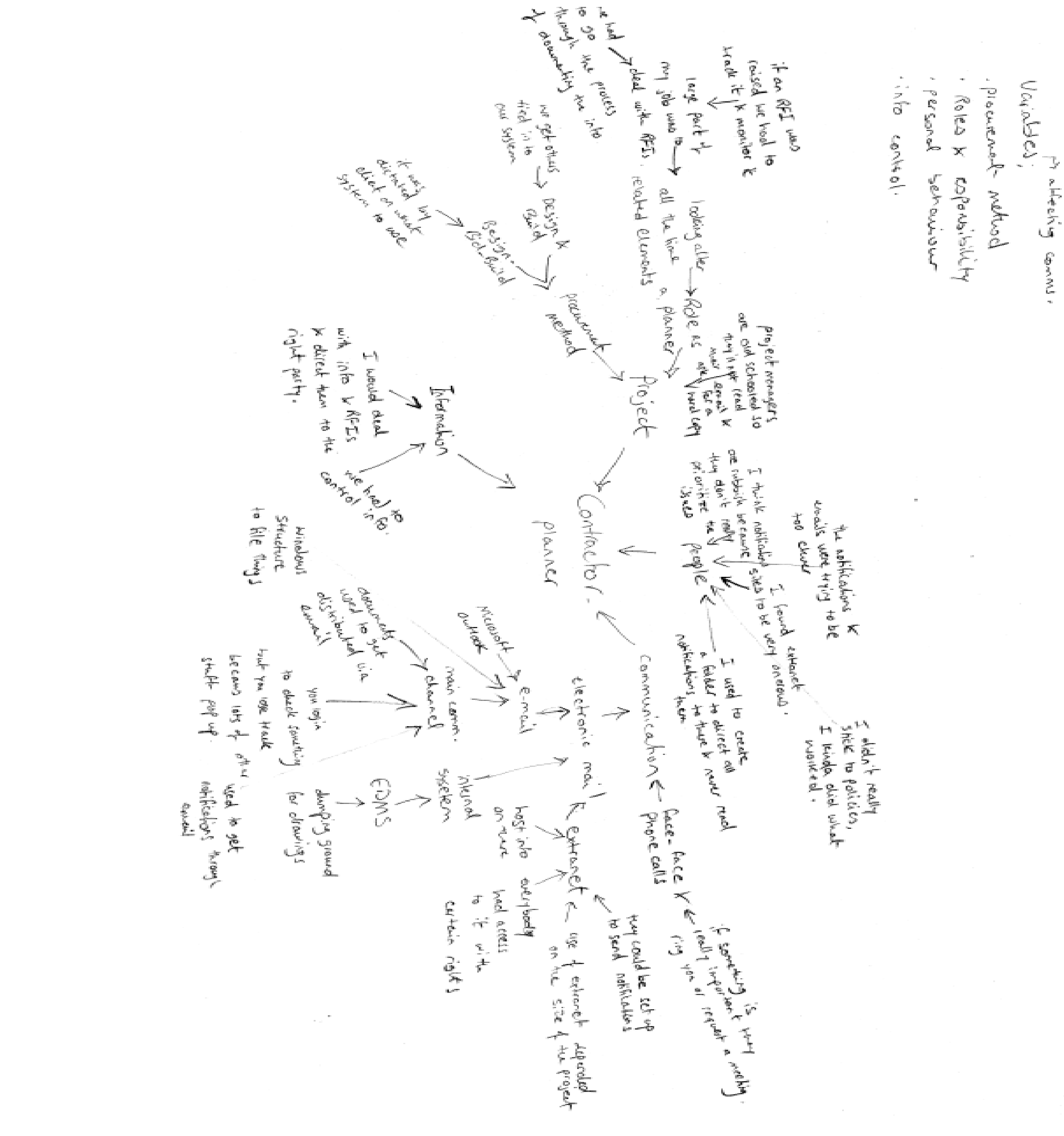
GLOSSARY

Term	Meaning
Asset	An asset is a thing or entity that has real or potential value to an organisation and for which the organisation has a responsibility
Asset information	Information that describes the current state of the physical and functional characteristics of an asset, at a level required to support the asset management systems.
Asset Information Model	Information Model(s) used during operations and maintenance that represent the Asset Information
Attribute data	Piece of data forming a partial description of an object or entity.
BIM Execution Plan	A digital information delivery plan, which details how the Supplier will collaboratively produce, share, manage and deliver the Project and Asset Information Model(s), in accordance with the client's BIM requirements.
BIM Protocol	A supplementary legal agreement that establishes obligations, liabilities and limitations on the development and use of the Project and Asset Information Model(s).
Classification	A consistent structure for grouping and relating information about assets, construction elements, systems and products.
Common Data Environment	The Common Data Environment (CDE) is a set of defined and managed procedures to ensure that the appropriate data is shared, as a single instance, from multiple data sources within the Project and the Asset Information Model(s). This environment shall be managed through specified controls, states and processes with the information and data held and controlled within integrated systems.
Construction Operations Building information exchange (COBie)	An industry recognised schema for consistent exchange of Asset Information.
Coordination	The alignment of tasks and activities to support common goals
Data	Raw facts and values stored either in a structured or unstructured format but not yet interpreted or analysed.
Document	Structured information conveyed as a physical and /or digital, typically immutable output to represent a standard type
Documentation	A collection of documents.
Drawing	A type of document, typically graphical in nature intended to communicate, instruct or record project or asset information.
File	A container for storing information saved in an electronic format.
Graphical data	Data represented digitally by geometry, with or without associated properties, spatially coordinated to represent and enable physical interaction

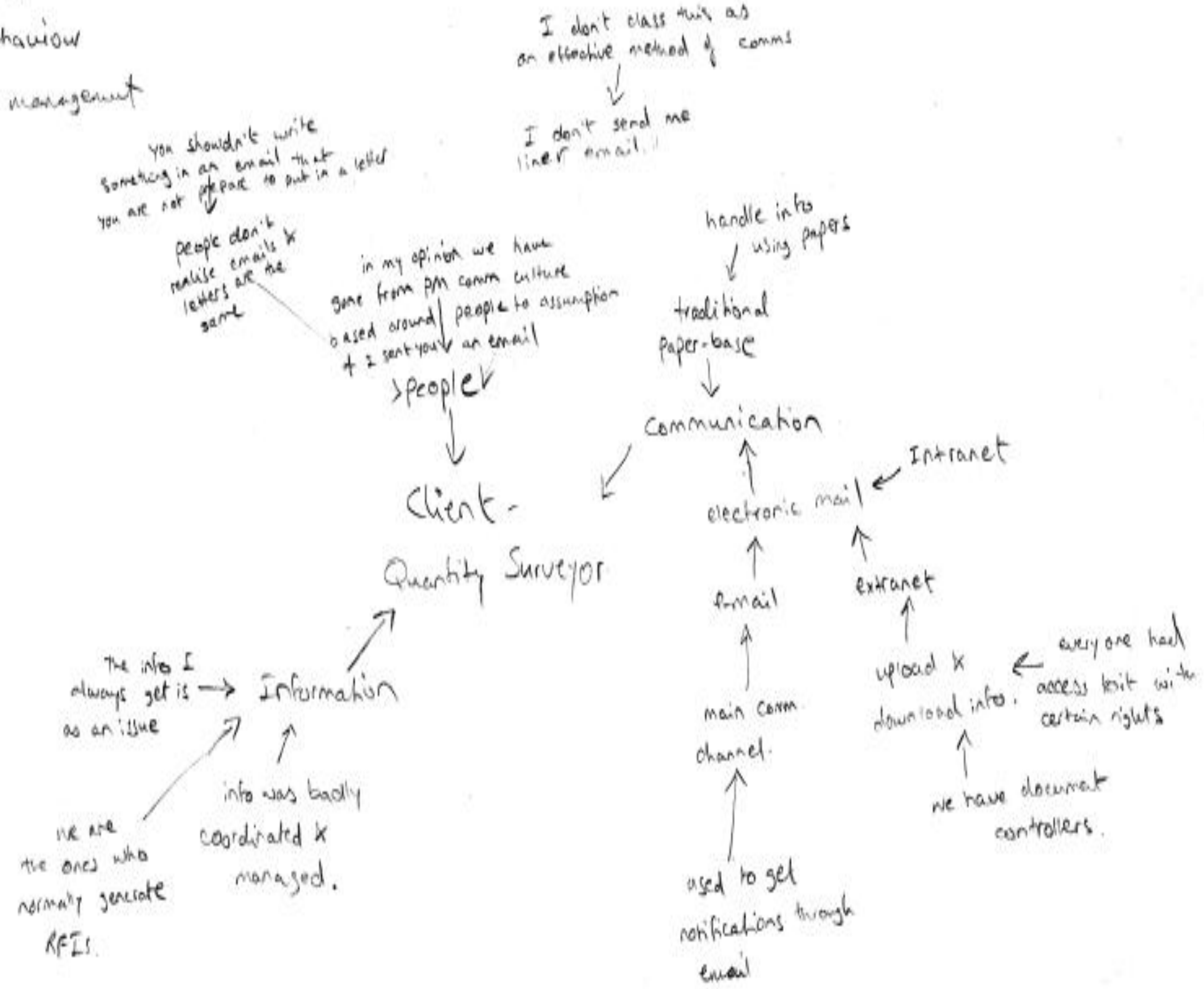
	with, or analysis of, an Asset.
Information exchange	Process of transferring information between project stakeholders.
Information management	Process of controlled production and management of project and asset information, from one or more parties, following defined procedures that ensure accuracy, accessibility and integrity of the information.
Information model	A collection of data and information about the project or the assets. Comprises of three constituent parts: Graphical Data, Non-Graphical Data and Documentation.
Information requirements	The information and data required to meet the business needs of the client.
Master Information Delivery Plan	A forward looking schedule of the individual deliverables required by the client, agreed for each project stage.
Metadata	Data describing one or more aspects of a file and / or its content. For example the source, capture method, title, project, location, key words, synopsis, security classification etc.
Non-graphical data	Data conveyed as values only, with or without associated properties but still potentially coordinated, to represent and enable the query or analysis of an asset.
Project Information Model	Information Model(s) produced, updated and maintained during the design and construction stages of the project that is required to describe both the physical and functional characteristics of an Asset before it is constructed.
Standards Methods & Procedures	A set of standards and procedures that provide a consistent approach to the production, management and delivery of the Project and Asset Information Model(s).
Validation	Validation demonstrates that the product, as provided, (or as it will be provided) will fulfil its intended use in the operational environment.

APPENDIX A – COGNITIVE MAPS



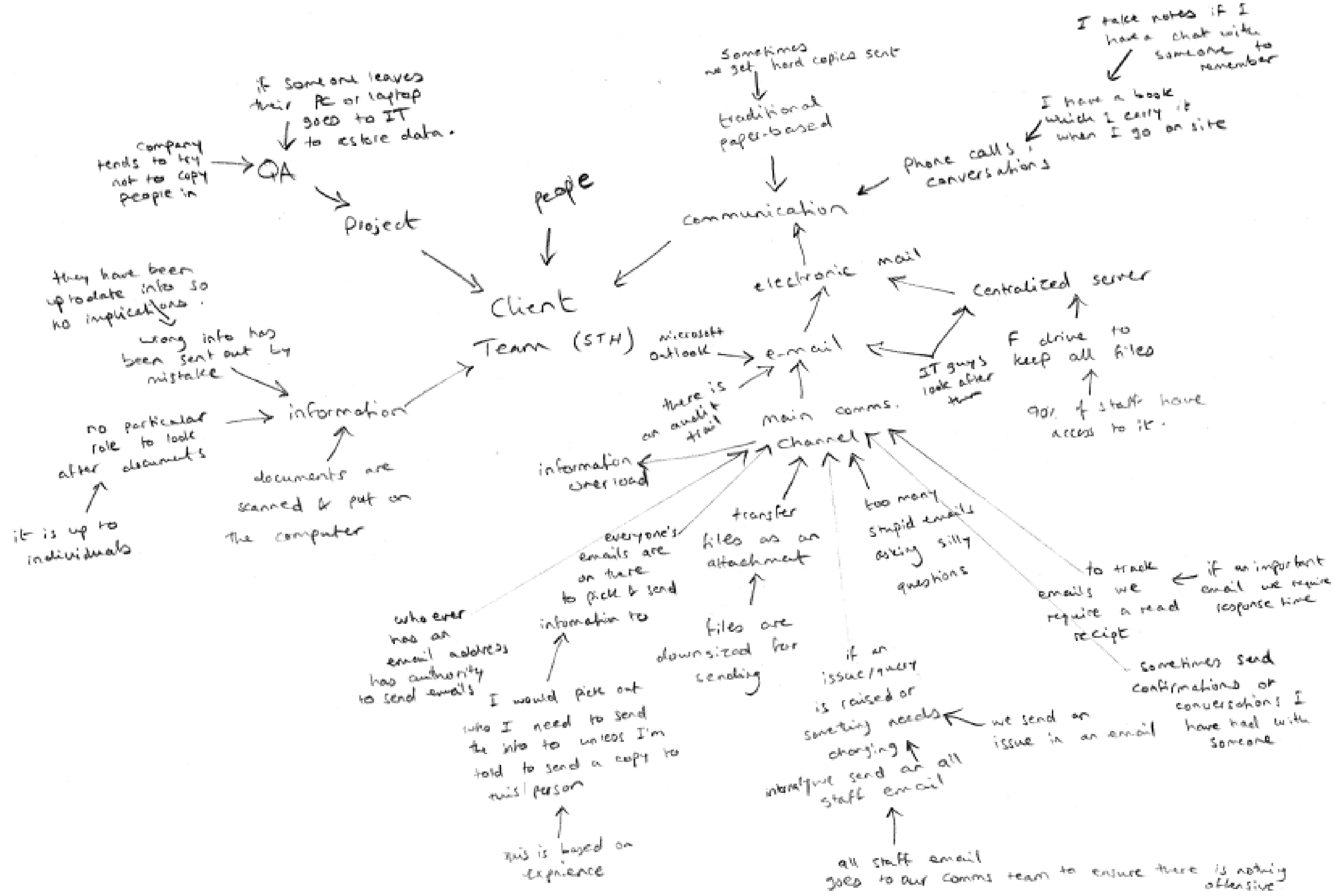
Variables affecting comms;

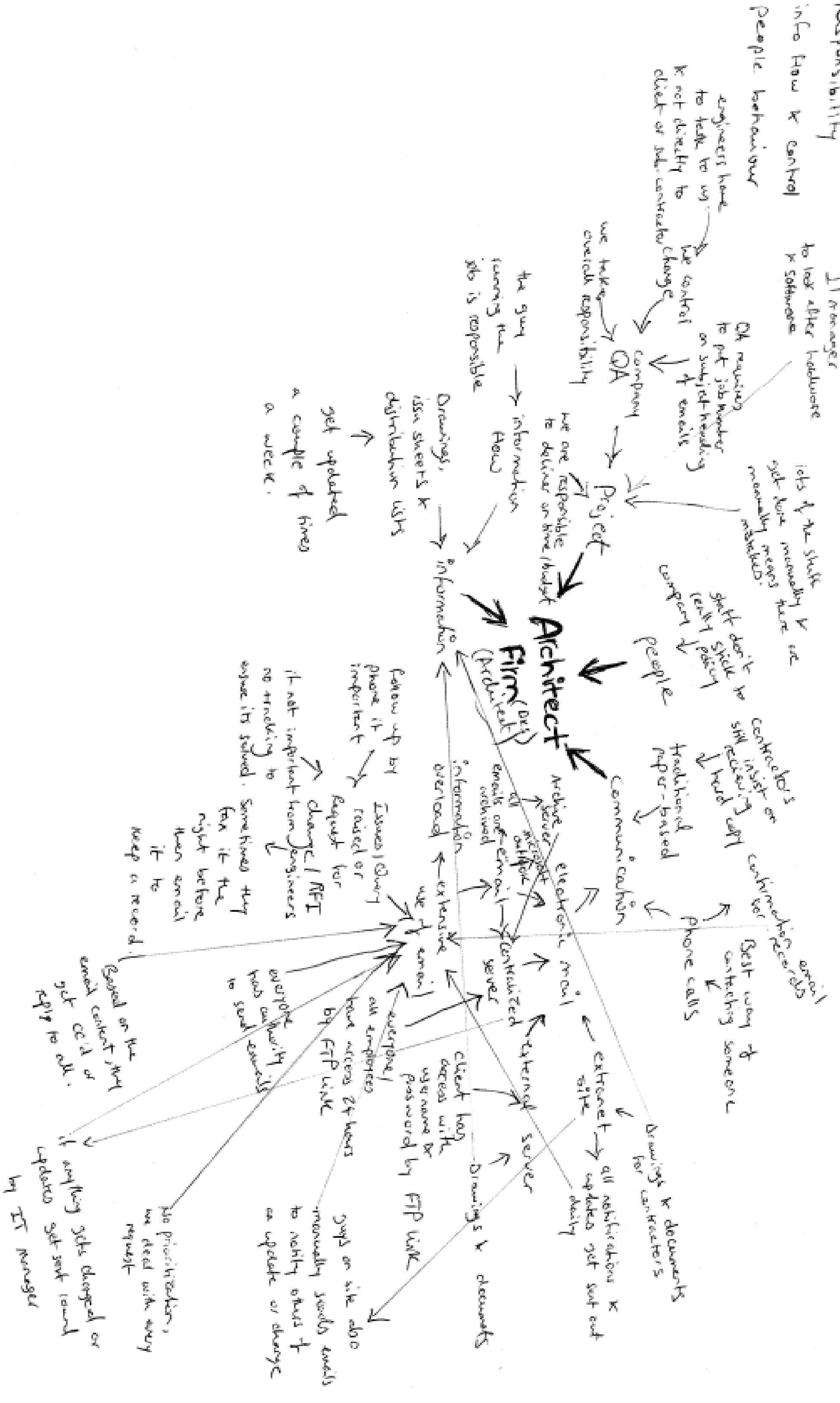
- procurement method
- people/personal behaviour
- info coordination & management

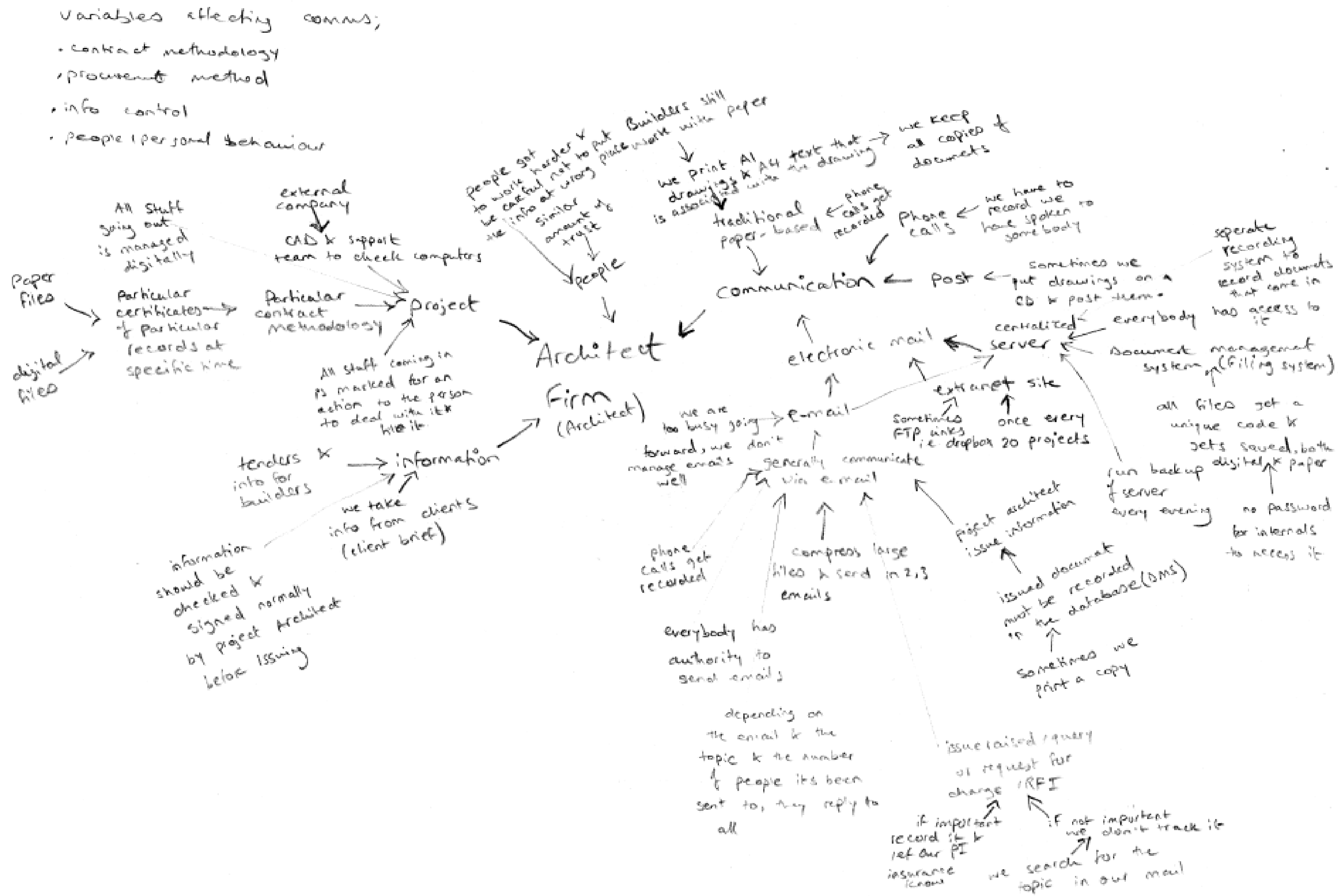


Variables affecting comms;

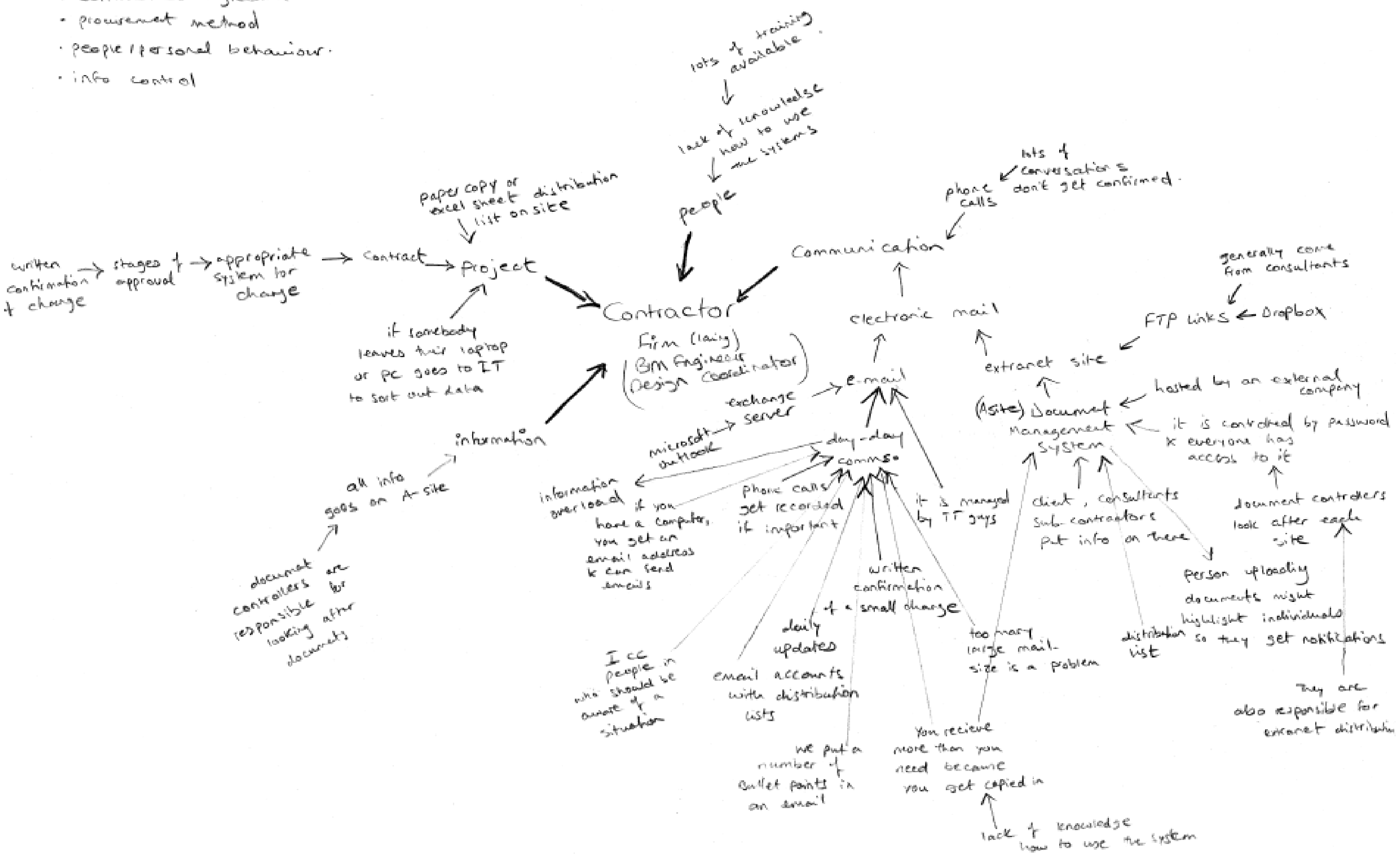
- company QA
- procurement method;




Variables affecting comms;
Company QA
Manual way of working
Responsibility
info flow & control
people behaviour
Architect Firm
Project
Company QA
people
communication
information
electronic mail
extensive use of email
Phone calls
extranet site
external server
information overload

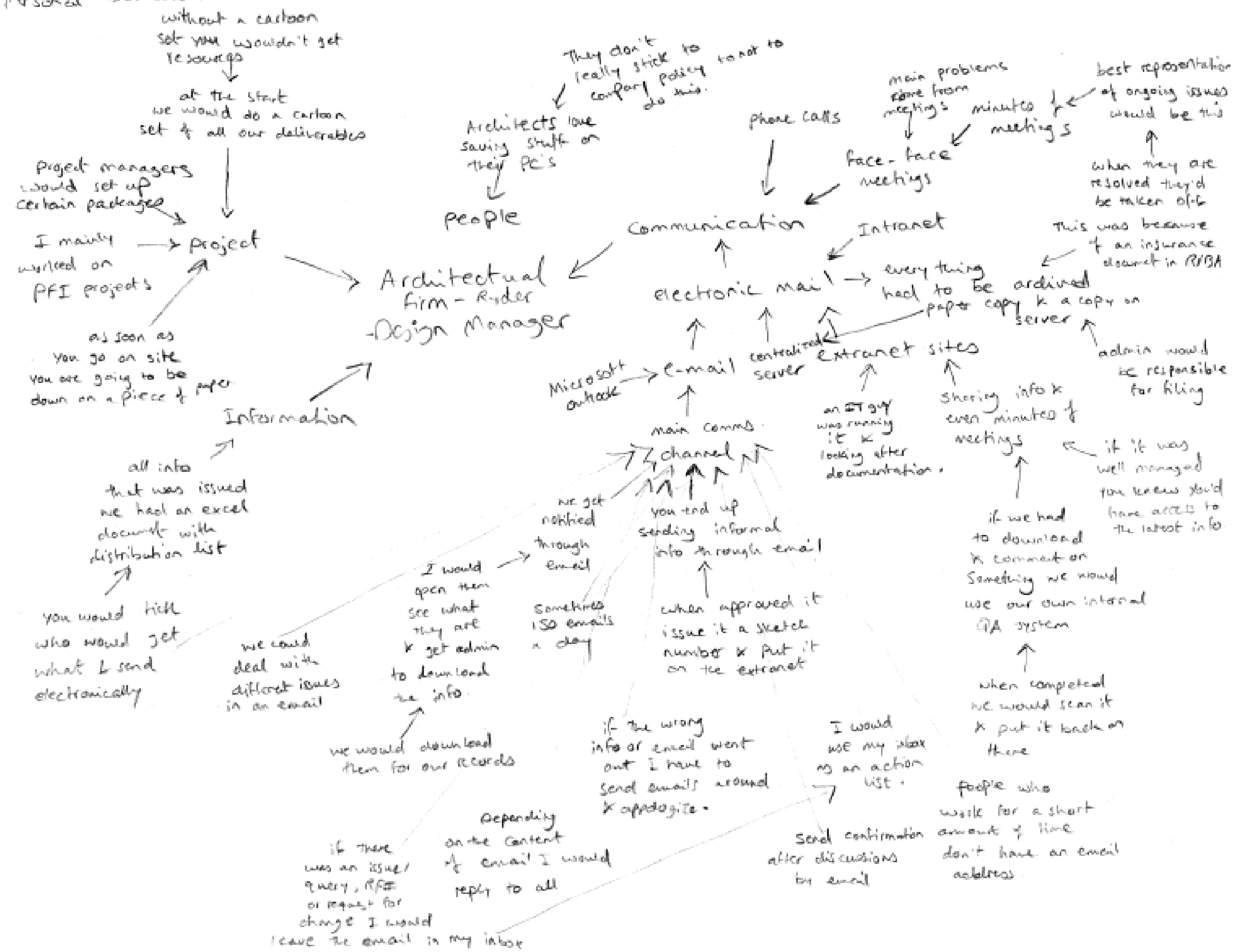

Variables affecting comms;
· contract methodology
· procurement method
· info control
· people / personal behaviour
Architect
Firm (Architect)
Project
information
people
Communication
electronic mail
post
Phone calls
e-mail
extranet site
centralized server
Paper files
digital files
Particular certificates of particular records at specific time
Particular contract methodology
All staff going out is managed digitally
external company
CAD & support team to check computers
All staff coming in is marked for an action to the person to deal with it & file it
tenders & info for builders
we take info from clients (client brief)
information should be checked & signed normally by project Architect before issuing
people got to work harder & be careful not to put info at wrong place
similar amount of trust
Builders still work with paper
we print A1 drawings & A4 text that is associated with the drawing
we keep all copies of documents
traditional paper-based
phone calls get recorded
we have to record we have spoken to somebody
sometimes we put drawings on a CD & post them.
seperate recording system to record documents that come in
everybody has access to it
Document management system (Filing system)
all files get a unique code & gets saved, both digital & paper
run back up of server every evening
no password for internals to access it
sometimes FTP links ie dropbox
once every 20 projects
we are too busy going forward, we don't manage emails well
generally communicate via e-mail
phone calls get recorded
compress large files & send in 2,3 emails
everybody has authority to send emails
depending on the email & the topic & the number of people its been sent to, they reply to all
project architect issue information
issued document must be recorded in the database (DMS)
sometimes we print a copy
issue raised / query or request for change / RFI
if important record it & let our PI insurance know
if not important we don't track it
we search for the topic in our mail

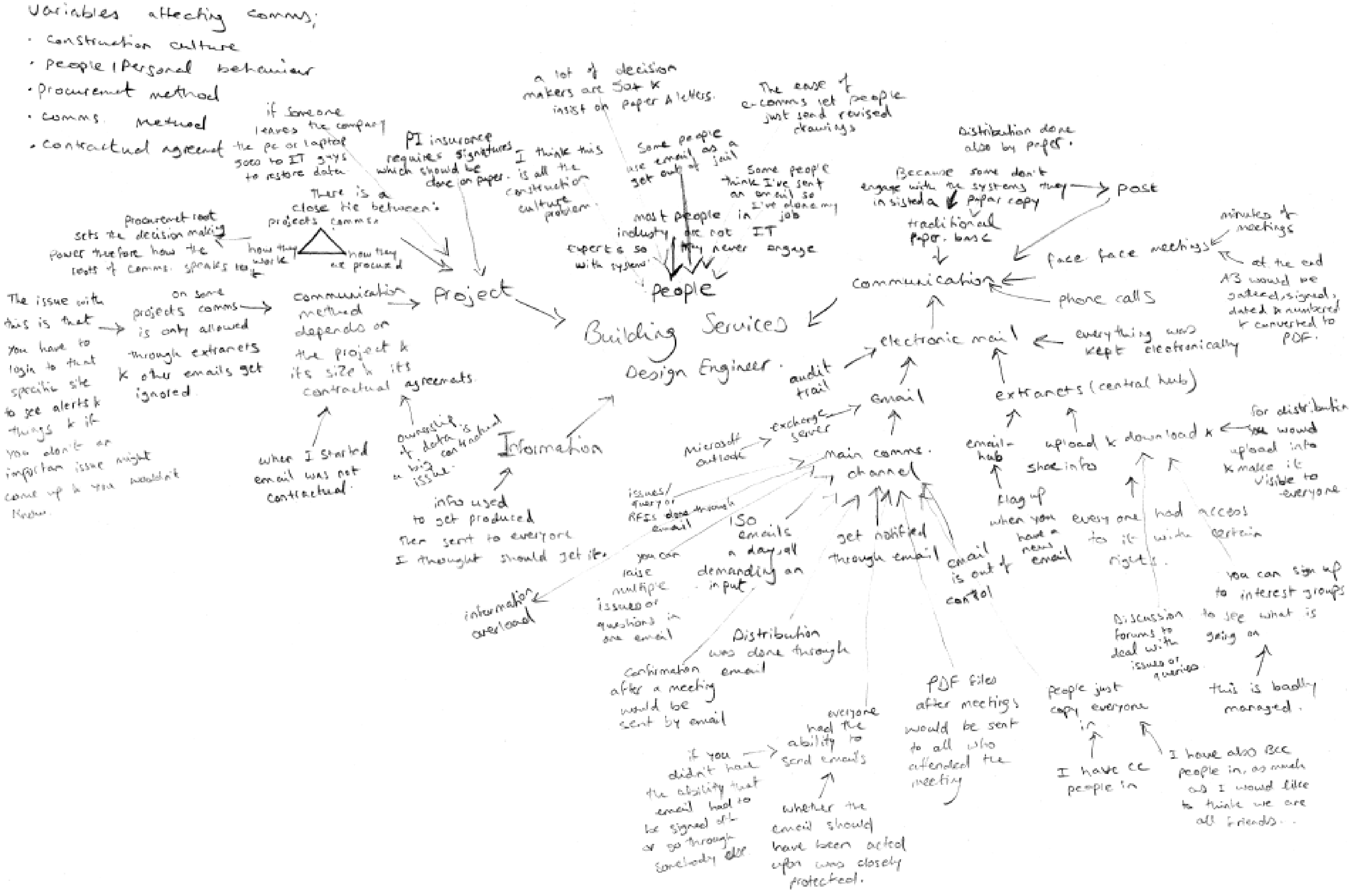
Variables affecting comms;
- contractual agreement
- procurement method
- people/personal behaviour.
- info control



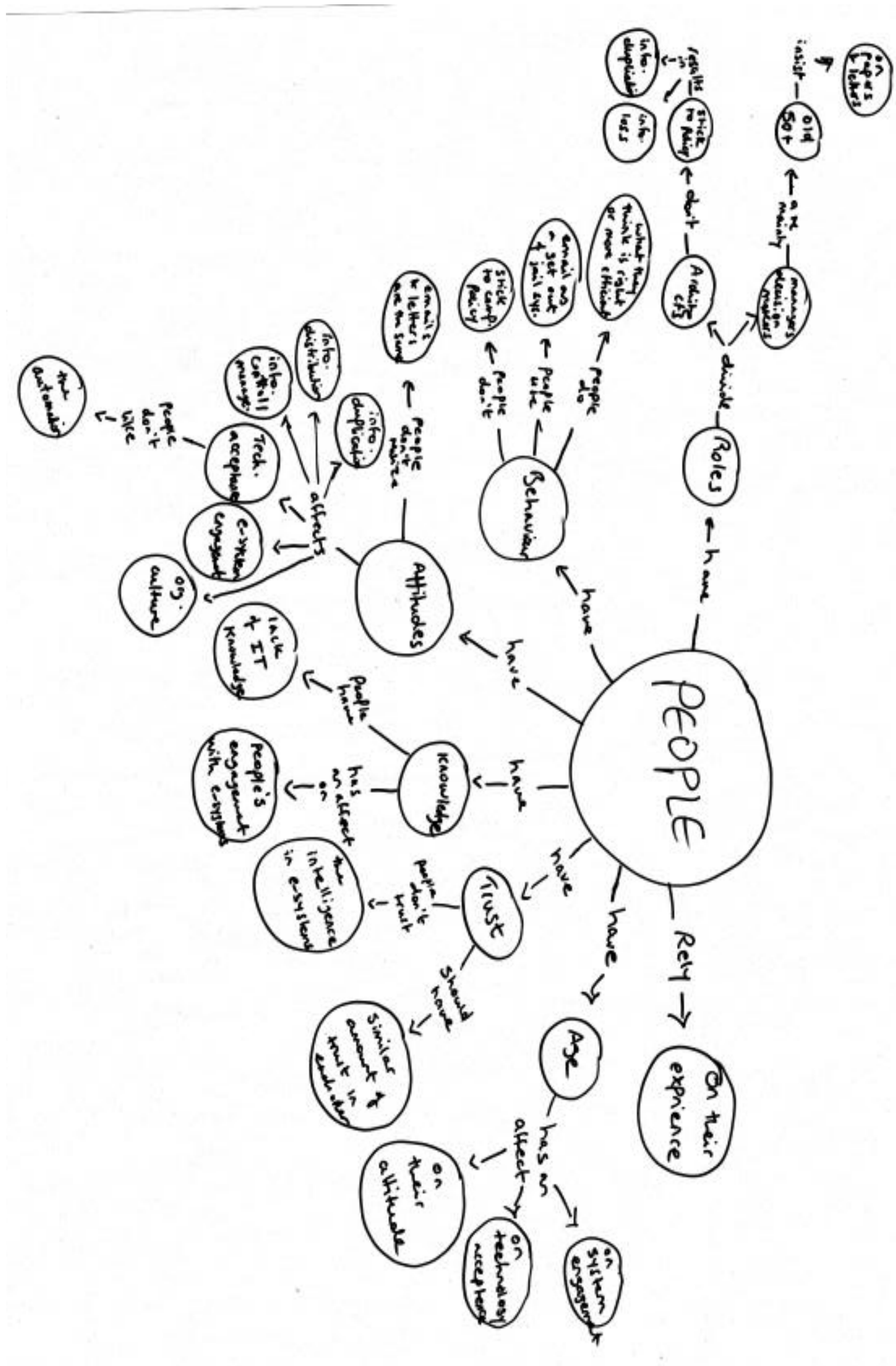
Variables affecting comms;

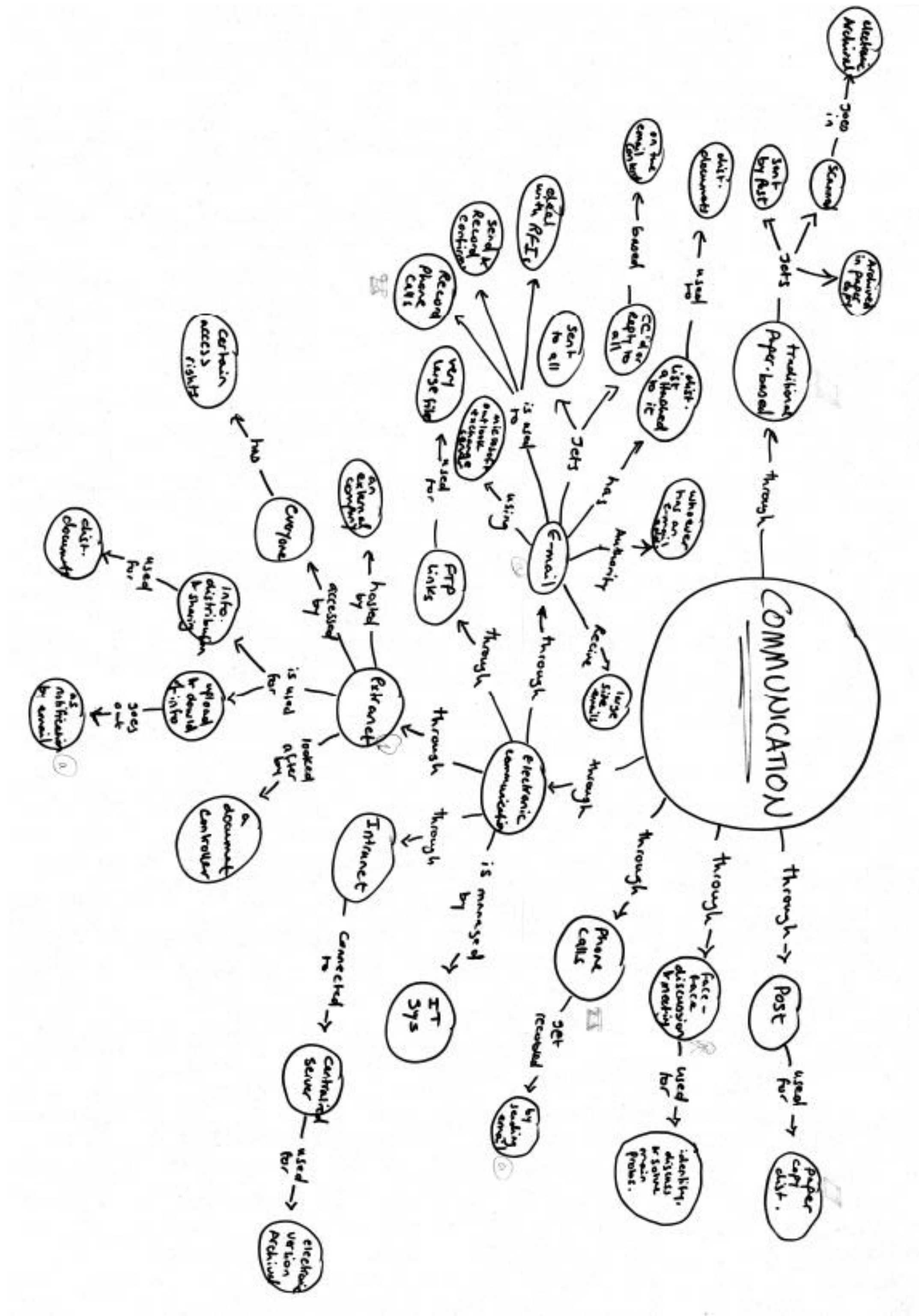
- Project type
- people's behaviour/personal behaviour
- Procurement method.





Variables affecting comms;
· Construction culture
· People / Personal behaviour
· Procurement method
· Comms. Method
· Contractual agreement
if someone leaves the company the pc or laptop goes to IT guys to restore data.
PI insurance requires signatures which should be done on paper.
I think this is all the construction culture problem.
a lot of decision makers are 50+ & insist on paper & letters.
Some people use email as a get out of jail
Some people think I've sent an email so I've done my job
The ease of e-comms let people just send revised drawings
Distribution done also by paper.
Because some don't engage with the systems they insisted a paper copy
Post
traditional paper base
There is a close tie between: projects comms &
Procurement root sets the decision making power therefore how the roots of comms. spreads too
how they work
how they are procured
most people in industry are not IT experts so they never engage with system
People
minutes of meetings
at the end A3 would be scanned, signed, dated & numbered & converted to PDF.
face face meetings
Communication
phone calls
The issue with this is that you have to login to that specific site to see alerts & things & if you don't an important issue might come up & you wouldn't know.
on some projects comms is only allowed through extranets & other emails get ignored
Communication method depends on the project & its size & its contractual agreements.
Project
Building Services
Design Engineer.
electronic mail
everything was kept electronically
audit trail
Email
extranets (central hub)
for distribution you would upload into & make it visible to everyone
when I started email was not contractual.
ownership of data is contractual & a big issue.
Information
Microsoft outlook
exchange server
main comms. channel
email-hub
upload & download & share info
info used to get produced then sent to everyone I thought should get it.
issues/query or RFIs done through email
ISO emails a day, all demanding an input.
get notified through email
email is out of control
flag up when you have a new email
everyone had access to it with certain rights.
you can sign up to interest groups to see what is going on
information overload
you can raise multiple issues or questions in one email
Distribution was done through email
Discussion forums to deal with issues or queries
Confirmation after a meeting would be sent by email
PDF files after meetings would be sent to all who attended the meeting
people just copy everyone in
this is badly managed.
everyone had the ability to send emails
if you didn't have the ability that email had to be signed off or go through somebody else
whether the email should have been acted upon was closely protected.
I have cc people in
I have also Bcc people in, as much as I would like to think we are all friends...


PEOPLE
have
Roles
divide
managers decision makers
old 50+
insist
on papers & letters
stick to policy
results in
info. duplication
info. loss
Behaviour
people do
what they think is right or more efficient
people like
people don't
stick to comp. policy
Attitudes
people don't realise
email & letters are the same
affects
info. duplication
info. distribution
info. control/manage
Tech. acceptance
people don't like
the automation
E-system engagement
org. culture
Knowledge
people have
lack of IT knowledge
has an affect on
people's engagement with e-system
Trust
people don't trust
the intelligence in e-system
should have
similar amount of trust in each other
Age
has an affect
on their attitude
on technology acceptance
on system engagement
Rely
on their exprience


COMMUNICATION
through
traditional Paper-based
Post
used for
paper copy dist.
face-face discussion & meeting
identify, discuss & solve main probs.
Phone Calls
get recorded
by sending email
electronic communication
is managed by
IT sys
Intranet
connected to
Centralised Server
electronic version Archived
Extranet
hosted by
an external company
accessed by
Everyone
has
certain access rights
is used for
info. distribution & sharing
dist. documents
goes out
as notification by email
looked after by
a document controller
FTP links
very large files
E-mail
using
is used to
gets
Sent to all
deal with RFI
Record Phone Call
large size emails
Scanned
Sent by Post
electronic Archived

APPENDIX B – NON-DISCLOSURE AGREEMENT

4 projects®

Global Software as a Service collaboration solutions

4Projects NDA – Mutual

June 2011

NDA – Mutual

1. 4Projects Limited, The Teleport, Doxford International, Sunderland, SR3 3XD, United Kingdom (hereinafter referred to as "4P") and **The University of Northumbria at Newcastle** (hereinafter referred to as "The University") hereby agree and make the following undertakings with respect to confidential information either party has provided, or has agreed to provide to each other relating to such purpose as defined herein below.

2. The parties hereto each disclose confidential information (including, but without limitation, technical, product, client and prospect information) to each other, for the following purpose (hereinafter referred to as the "Purpose"):

   To enable The University to conduct analysis into the patterns of usage of the 4Projects '3G' collaboration data, across 'real world' projects. To facilitate this, 4Projects will provide a custom data-set that has been suitably filtered and anonymised to protect the IPR and privacy of the original client data. The outcome of this study may result in a Phd Thesis, which, subject to the written mutual agreement of both parties, may be published publically as per standard academia protocols.

3. The parties hereto undertake, each to the other, that with respect to the confidential information disclosed that it shall:

   i. Treat it as confidential and apply no lesser security measures to it than they apply to its own confidential information;

   ii. Not disclose it to any third party without the prior written consent of the other;

   iii. Use it solely for the Purpose set out in paragraph 2;

   iv. Hand over to the other all documents, copies and notes containing the information within fourteen (14) days of receipt of a written request from the other.

4. The requirements of Paragraph 3 shall not apply to any part of the information supplied by either party to the other which is:

   i. Made public at any time by the party disclosing, or by another with the permission of the party so disclosing;

   ii. Legally in the possession of one party before the date of disclosure by the other;

   iii. In the public domain.

5. With respect to the confidential information specified in Paragraph 1, this Undertaking constitutes the entire agreement of the parties thereto and supersedes all prior and contemporaneous undertakings, agreements, understandings and negotiations relating thereto.

6. This Undertaking shall be governed and construed in accordance with English Law and the parties hereto submit irrevocably to the exclusive jurisdiction of the English Courts of Law.

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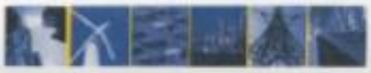
a leading software company delivering global Software as a Service collaboration solutions



Signed:	
Name:	S. R. LOCKLEY
Title:	PROFESSOR
For and Behalf of:	UNIVERSITY OF NORTHUMBRIA
Dated:	19/7/12

Signed:	
Name:	Sonia Zahiroddiny
Title:	PhD Student
For and Behalf of:	University of Northumbria.
Dated:	19/7/12

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APPENDIX C – PILOT STUDY INTRODUCTORY LETTER

Introductory Letter

My name is Sonia Zahiroddiny and I am a Doctoral Researcher at the School of Built and Natural Environment at Northumbria University. I'm investigating the impacts that Building Information Modelling (BIM) will have on electronic systems of communication in construction. My specific interest is in the interaction between E-mail based communication and the information in building models and the ways in which the information will be exchanged using email tools to prevent information overload. The aim is to investigate the integration of BIM, E-mail and work flow management technologies to improve the effectiveness of communication within complex construction procurement teams.

I would be most grateful if you would volunteer to assist in a pilot study that I am conducting by granting an interview. No more than one hour would be required. This interview is for me to gain a better understanding of issues effecting communication in construction. The results will be used to prototype a communication system model and the time scale for the pilot study is about 6 months. I will seek your consent before the interview starts as I intend to record the interview. Full anonymity and confidentialityis guaranteed for all participants that take part in the research and any work to be published as a result of this research will be done so in agreement with all parties.

Thank you in advance for your assistance.

Yours sincerely,
Sonia Zahiroddiny

2nd Floor,Wynne Jones
School of the Built Environment
Northumbria University
Newcastle,UK
NE1 8ST
Tel: 0191 227 4301
Email: sonia.zahiroddiny@unn.ac.uk

APPENDIX D – ETHICS FORM EXAMPLE

Appendix B

northumbria UNIVERSITY School of the Built Environment

RESEARCH PARTICIPANT CONSENT FORM

Name of participant	Jane Matthews.
Organisation (if applicable)	Northumbria University
Project title	
Researcher's name	Sonia.
Programme of study (if researcher is a student)	PhD.
Supervisor's name (if researcher is a student)	Steve Lockley A Claudi Benghi

Standard statement of participant* consent

I confirm that

I have been briefed about this research project and its purpose and agree to participate* ☑

I have discussed any requirement for anonymity or confidentiality with the researcher** ☑

I agree to being audio taped / videotaped during the interview ☑

** Participants under the age of 18 normally require parental consent to be involved in research.*

*** See the section below for any specific requirements for anonymity or confidentiality*

Signed .... **Date** 18 February 2011

15

Specific requirements for anonymity or confidentiality

Standard statement by researcher

I have provided information about the research to the research participant and believe that he/she understands what is involved.

Researcher's signature .... **Date** 01/02/2011

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APPENDIX E –INTERVIEW TRANSCRIPTS

Transcription –DKS Architects - Principal Architect

Sonia: Right, ok Mark I've started recording the interview,

Architect: Ok, no problem.

Sonia: Can I firstly ask what is it that you do?

Architect: As a firm, or personally?

Sonia: As a firm.

Architect: Right, DKS architects work in various sectors, so probably if we list them; education sector, commercial, healthcare and housing are our prominent sectors. But we generally do anything that comes in we've got a few sort of grand design houses to do as well for people. We do some churches, so fairly broad we tend not to specialize but inevitably in this climate that's how you win you work.

Sonia: So all these different projects, you deal with different drawings and information how do you deal with them? Do you deal with them via email? Do you have extranets? Intranets?

Architect: We are a medium size practice, that's a definition used by RIBA to class any practice I think that employs more than I think it's something like 5-50 people. So we are not so practitioner we are kind of in the middle. As a medium size practice we use email extensively. We don't actually have an extranet site but everybody has access to the server out of hours from home. So we have a FTP link that enables them to do that. We've never really needed an extranet as such. I guess that is similar sort of thing but perhaps if we had another office, we might need a more permanent connection between the two but we are a ... office so we haven't needed it.

Sonia: Right, so I'm guessing if you don't have an extranet site you won't get any sort of notifications in terms of when things get updated, or things get changed by someone? How do you actually notify each other about that?

Architect: When you say each other do you mean ourselves working together?

Sonia: Yeah, in your firm.

Architect: Well, we use email a lot and we have an IT manager who is responsible for looking after all the hardware and software licenses, etc. And he will send updates around the office; the emails are set up in such a way that you can either send them individually or you can send them to the whole office by one click. So he would send us updates. And all the updates from the computer will all happen automatically over night or on a weekend.

Sonia: So everything is centralised?

Architect: Yeah.

Sonia: Right, what if somebody else makes any changes to any information or drawings outside your firm? How does that work?

Architect: It is very important that from a QA point of you that we control change, because you could imagine with having live projects we don't people changing our information, or information that's going to be used on site without our knowledge, so traditionally the architect is usually the lead for the design team, so we take overall responsibility and with that we have ultimate control so if a structural engineer for example wants to change something he has to come through us, he can't talk directly to the site or the contractor.

Sonia: But how does he communicate with you?

Architect: He would ring us up, he would email us and say I need to make a change and then he would send his information to us by email and we will update it. We are now into building information modelling, so things are slightly different in that with a lot of projects we are sharing a model but once again we take responsibility for that model. So if other consultants make a change they send us their model and we insert into ours, so we must have control over it.

Sonia: So if you do any discussions over the phone, how do you confirm it? Would you send a confirmation email?

Architect: Yeah, generally. Particularly if it has contractual implications, we have to make sure it's recorded and then as the lead consultant we would instruct the contractor to make a change. It's very important that the architect does that because we need to take a view of the bigger picture. Because not only we are responsible for delivering the project and the performance of all the consultants, we are also responsible for delivering the project on time and on budget, so another consultant might want to make a change but by controlling it we can make a judgement whether that change is absolutely necessary.
Sonia: So do you actually own the model? Going back to talking about BIM. Do you own it? Or the client does?
Architect: Yeah we do, it depends on the client. It is quite new to our clients. We don't work with very big organisations. We are starting to work with the NHS who demands that everything is done in BIM. So things may change but at the moment we take control of the model and we take ownership of it. Saying that I spoke to Steve Lockley about this at the university and he said that a lot of companies are reluctant to give up that model to their clients. I can't see that being necessary in the long term because that's what they are going to expect so I don't think it is right to say you can't have the model, it belongs to us and I'm sure that will be addressed over forthcoming years.
Sonia: So going back to email again, do you think you deal with too many email a day? Obviously your communication tool is email.
Architect: Yeah probably is. Yeah, I agree with that
Sonia: Do you have any archival system where you store all the emails that you receive?
Architect: Yeah, all emails that come in are then transferred; obviously job specific emails are transferred into a folder where we store all of the emails relating to that specific job. Every job in our office has a number and a folder on the server and that gets moved across into there. It is supposed to happen in a weekly basis but it is up to individuals to make sure to transfer them across and then when a job is complete it then gets moved to our archive server, the whole thing, including all the emails related to that job, all the drawings, all correspondents, everything.
Sonia: What if somebody doesn't transfer all the emails to the server? What if they forget?
Architect: That's a fair point. I'm bad at doing it because it takes time and my inbox is massive into the 1000s because I don't do that. It would be good to have an automated system that detected a job number and it moved across automatically.
Sonia: What about the distribution list? How does that work?
Architect: Distribution to other consultants?
Sonia: Yes.
Architect: It depends on the job. How many other people, because you can imagine on a very complex job there will be all sorts of people, it won't just be the usual consultants. There might be some specialist people. So they would be on the list. There is a particular job we are doing at the moment which is a refurbishment project for a fire station and what we have set up is a Box Net is called. It is an extranet place where we can we can put correspondents, models, drawing, etc and then everybody has access to that. What the guys do who are running on the site they send an email to everybody sort of manually to say please note there is a new drawing in box net waiting for you to access and this supersede previous work.
Sonia: So there is no version control, I'm guessing?
Architect: Well, that controls it. What we have I can give you that if you want before you leave, it is a drawing issue sheet so what that does is it lists all the drawings that we have created or correspondents. It doesn't have to be a drawing, it can be specification something, a written document and a date across the top and when it was issued, what the revision number was and then at the bottom there is a distribution list, so it lists all the people that get it and you literally electronically tick boxes who is going to get the information and then that is a record and at any time any consultant particularly the contractor can take a look at that list and see what the latest revision is for that particular drawing.
Sonia: What if they say we never received the email?

Architect: By having that list and sending that out, a lot of contractors still insist on receiving hard copies probably for that reason that they need to make sure that they have received it. We've never had a problem I guess very rarely that a contractor have tried to use whether legitimately or otherwise the comment that they didn't receive something. Because drawings get updated probably a couple of times a week. If for whatever reason they miss a revision they'll be sent another revision or if only one drawing goes out they'll be sending a new drawing issue sheet and from that they can see that last week they also got a couple of other drawings so they've always got that drawing issue sheet at anytime. This is where; because we now use this electronic system it's like an external server, by using that they can go in there at any time and always see what the most recent drawing is. So in that server we'll have current drawings, superseded drawings. So even if they didn't get the email that said there is a new drawing has been relisted and they should always refer to that.
Sonia: So is there a role responsible for all these management, all these information flow?
Architect: It is usually the person who is running the job. On this particular job there are a few guys who are running it from a technical point of view, maybe 2, 3 people and there will be a more senior person there who is taking the responsibility if the job but the people who work for him know the procedure. So the guys in control, have you updated the drawing sheet? Have you put it on box net yet?
Sonia: And does everyone in your firm have authority to send emails?
Architect: Yes.
Sonia: It is just some companies, don't.
Architect: No, everybody has authority to send emails; we've never had a problem where someone sends something inappropriate. I think everybody is pretty mature about this and if they've got a technical query or they think that there might be a bigger issue they would talk to either the next step up, a senior person or they might even talk to a partner because we are only relatively small practice so there is usually a partner around to ask.
Sonia: I was wondering if anyone has ever sent the wrong information to someone, or sent information to the wrong person.
Architect: I'm sure at some point in time somebody has sent the wrong information to the wrong person but nobody is perfect so if it was a legitimate mistake and it was identified and addressed straight away then we would accept that you know, as long as that person whose made the mistake puts their hand up straight away and deals with it and doesn't just ignore it.
Sonia: And if there is an issue raised about anything how do you deal with it? In terms of, how do you make sure that the issue has been tracked and solved? Because you know somebody might say, right there is a problem with this project at this point and send an email round to everyone and but how do you actually track it to ensure that the issue has been solved?
Architect: That is a good question. We don't track it, we don't insist on read receipts unless it's a very important thing, if it was a like you say there was a particular change that happened, you know it might have health and safety implications or huge cost implication we probably tick the box to make sure everybody has received it and probable the old fashion way just following it up by phone to say did you get the email from me? Are you aware of it? Are you going to deal with it?
Sonia: You don't actually confirm it by sending an email to ensure it has been dealt with and definitely solved?
Architect: What normally happens in these stances, from a construction point of you, if there is a query raised, obviously if we raise a query or make a change we are in control of it we tell the contractor they need to make this change that is an instruction, this is an instruction. But what normally happens is if there is a problem and the contractor might ask us, he might say you have asked me to knock a wall out and we now found that there is a lots of servicing pipes, etc in it what do you want me to do? So what they do, they issue usually previously by fax, they starting to do more by email a request for information which is sort of RFI so we would respond to that. It usually says on it how many days we have to respond. And that will vary because it depends how significant the question is. So if it has an immediate implication it might say i need a respond within 24 hours otherwise it's going

to delay the project. So we would have to respond straight away and we need to make sure we send it back and we send it back with the date and the time so that gets recorded and goes in our file.

Sonia: What about any other of communication? Do you have a policy about how quick to respond?

Architect: It is all very fluid because of the nature of the business we are in something's are not important, a contractor might say you asked me to get a certain type of door but I can't get it. You know, what do you want me to do? Something like that screw the door so we probably got weeks to address it. But other things like I say are more important. And if there is something that is very urgent the best way of contacting somebody is to ring them, you know we have all got mobile phones so we can be contacted at anytime.

Sonia: Do you deal with multiple issues in one email? Or is there like a policy where if there is an issue you have to deal with it separately in an email just so you have a record of it

Architect: No, we don't do that. As long as it is clear, we can list more than one issue in one email. Can't see that being a problem.

Sonia: And if you have an issue, i.ee relating to windows, when you send an email do you have to have a specific subject heading?

Architect: Yeah, there are quite lacks on that. Our QA policy probably says we should put the job number at the top of the email, in the subject, so that it is easier for the person at the other end and it's easier for us. Sometimes it depends on the client, in the past I have had clients say to me, every email I get from you it needs to have this reference in the subject heading. So that's fine so if that's the procedure we'll run with it. But that usually comes from other people rather than us.

Sonia: And do you email in a structured way? Do you use everything, i.e. the red flag, use importance of an email to show how important how important an email is?

Architect: As far as I'm concerned every email is important, so we've never really felt the need to decide if it needs to be red flagged or not. Sometimes we get them from clients that got red flags on, but we would respond to every request. You know we don't really prioritize we just deal with them.

Sonia: In terms of your inbox, do you create folders to save email in different folders?

Architect: We have folders for all the jobs that we've got. So they get transferred across manually to those folders. And if there is personal stuff they'll go in personal ones.

Sonia: And if you want to transfer any large files I'm guessing you use the external server?

Architect: Indeed, another thing that I've done with our clients is I have given them a FTP link to our server with a password and our IT manager set that up for me and this is quite attractive to our clients, I can say to them you can have 24 hours access to all the work we've done for you, whether that is drawing or reports.

Sonia: What software are you using for your email? Is it Microsoft outlook?

Architect: Yes it is. Just going back to setting up this server link, erm... I can't remember what I was going to say now, it was something that would be very relevant.

Sonia: About the FTP, giving a link to the client.

Architect: Come back to me, I can't remember.

Sonia: Do you ever use CC, BCC? when you reply do you reply to all? Or just reply to that specific person who sent you the email?

Architect: It depends on the content of the email, because generally if an email comes in and those are the people who have added to that email for a reason, obviously they need to see what the response is, so generally you would reply to all. However because that email might include a whole loads of people, might include stakeholders, clients, contractors, consultants, consultants you might want to have a quite discussion with the client to advise them directly of what is going on and how we are going to deal with it so you might exchange some other emails outside of that loop just to protect their interest. So the contractor might say you need to make a decision on these two things that I've told you about and if I don't hear from you in a week then that is going to japitize the program and I might say to the client on the quiet that is not true you have got more than a week, do not rush into this decision. Do you see what I'm saying?

Sonia: Yeah, so you don't blind copy everyone in?
Architect: No, actually it is worth saying; there have been a few instances where people get mistakenly copied in as you get probably in all businesses. It would be really good to iron that out somehow, because fortunately there has never been an instance where something has been said that has huge consequences, but I've done it myself, you have moaned about somebody or you have said something that is just not something you want somebody else to read and they have seen it because they were copied in by mistake.
Sonia: Is there no guidelines, or any policy about this that you should be more careful about it?
Architect: We've got a practice policy for everything that list things but we probably don't police it like that, don't forget we are quite a small practice compare to most businesses in the UK, so it is all quite small. I've just realised you haven't got a drink, would you like a drink? You have driven all this way?
Sonia: Oh thank you, I'm ok, I'm fine thanks.
Sonia: Going back to BIM, now that we have just discussed all of this, do you think BIM will have any affect in terms of how people communicate?
Architect: I think it should do, when you started off explaining what you are doing I think there is a real opportunity trying to link the two together, because a lot of the stuff that I've just explained to you happens manually. And manually means that there are mistakes. And it doesn't get done. So yeah, if there is any way to link the two up, I mean we are aware that with BIM there are ways of circulating information, and automatically advising other people and letting people coming and having access but the worry is we've still got to have control over that. I mean if you want to have a talk to some of the technical guys you can. Because they were they were telling me about automatic revisions on BIM models where it can set up an automatic revision every time you do something and they have turned that off because what happens is, we might change a drawing several times before anybody else sees it , it gets revised 3,4 times because people dip into that drawing and come out before we want the contractor or whoever to see it. So that is why we have turned that facility off and we still do it manually. Because we want to choose when it gets revision. Otherwise there will be so many revisions people would lose track they seem think there will be 4 times as many revisions.
Sonia: Is there any problems in terms of transferring different file formats?
Architect: What we have started to do, we use Revit for our BIM and we are now only working with consultants that can use Revit or can work with it. So what is actually doing is narrowing the people we can work with, if we are using BIM and somebody else still in 2D, we end up having to do their work and redrawing in 3D so it is much easier just to say, right these are the companies we know that can work with BIM and its worth while working with.
Sonia: Do you have a role in terms of looking after BIM? You know we have CAD managers? Do you have a BIM manager as well? Or is it just the technical people looking after it:?
Architect: Yeah, the IT guys will probably take all responsibility for BIM but the guys coming through from universities now, the students, they are all so familiar with it, we can allow them to use it really. As long as they follow our protocol it is fine.
Sonia: That's all the questions I've got.
Architect: Well' that was easy.
Sonia: Well thank you so much for your time, I'm going to stop the recorder now.

Transcription – Architect - Design Manager
Sonia: could tell us a little bit about what you do?
Architect: I am an architect, which means we take information from our clients , about what they want to build, our particular office deals mainly in housing , meaning its sponsored by housing associations or local authorities, mainly in the middle of Scotland , we also do similar work for private developers , so we might build one house , 5 flats , couple of hundred houses or couple of hundred flats. We take that rate from clients brief so to develop the design for them getting the various approval from building control planning

approval , getting tenders and information for builders so they can give us a price, getting the approval from the client for that price to be paid appointed to the contractor they managing a quick formal contract procedure that’s defined very clearly and taking that right through monitoring the work on site , reporting to the client, authorising payments for the work and then joy for seeing the building finish.
Sonia: Great, all these joins and information, do you send these information by emails? Do you use extranet?
Architect: It depends on the scale of project , the attitude of the client and build of the team, so every design team normally can , is an architect, structure engineer, at least a surveyor who look at the price of things, and sometimes other specialists mechanic engineers, landscape architects, interior designers , so design team can be between 3 and 10 people, then you have got to communicate with the client and with the contractor, this moment in time we probably in the caps of communicating all in paper to communicating partly paper and partly email and it will be sometime before it s only digital data, at the moment because the person who is building the building tends to still work on a piece of paper, pin it on the wall and then have it there when working, paper is still important so we still print on A1 size drawings, pretty much everything we do, and we will print on A4 joins to match all of the text that is associated with that , specification, a description what this table is made of and how its put together whether in the building, or be on an A4 piece of paper, or an A1 drawing, so they are fundamentals . There are other things, because we got particular contract methodology in architecture, we have got to have particular certificates of particular records done at specific times that we might maintain, at the moment that’s again is a mixture of paper files in the cupboard and the digital files in our database and like most architects we are sort of modelling through at the moment between one and the other. But when we communicate its generally email, extranet maybe once every 20 projects and usually in bigger projects.
Sonia: so like if you got any large files, how would you transfer them?
Architect: First of all we try to compress them as much as we can then we will send them to 2,3 emails if we have to or we put them on a cd and send them , sometimes we use drop box and sometimes we use extranets but that tends to be quite rare because most of the files the graphics files are fine, they are communicate able. The size has not been a problem although if it is an extranet and drop box are the products that we can use , but it’s not nor email with either a CAD file, DWG file or PDF file which is a fixed formula file which we would use .
Sonia: do you have any formal support for archiving because I am guessing you are using email as information management as well as email?
Architect: Interestingly we architects have 3 ways of approaching the data , one is to keep all the prince and copies of documents and the files , the second one is to use the appropriate management system, we use a system called archetype, it’s actually designed by architects so that when you create a document whether its a letter or a drawing or an email, it arcades a unique code and it puts it in a particular place in the project database so that everybody have enough access to it and everyone knows where it is and it’s on your server , when it is on our server, we run backup of our server every evening and I take one home the next day, so we always got the latest version of whole data base, it’s the whole data , I think we have probably got 700gb and we can back that up now days, it used to be lots of floppy discs but we are well passed that now , we are actually beginning to look at remote back up , because we have a technical CAD and support team, it’s an external company, we pay them so much a month to come in and just check the computers and they are now offering a facility which is come in our server and back the data remotely , so we are on the process of thinking about that .
Sonia: so you don’t actually have an IT department?
Architect: As a company there is only 12 of us, so we have 8 architects, I tend to build up of the scale of how to plug in the kit to make sure if falls to pieces and put it back together again but we now do employ an IT company for the kit works, making sure the network works, make sure phones and communications are right , when we come down to

architectural data we take care of that because we want to take control and we want to know where it is

Sonia: so for every project all the information is centralised on a server? Right?And all the people on the site, would they have access to that?

Architect: Everybody is networked , all the projects are numbered so there might be 3 or 4 people looking at particular projects at the time and they are know or should know where the information is kept, sometimes they put it back in the wrong place , but generally we have got , again as architects ever since we have been using CAD and computer systems for about since 1986 so we have got quite strong data structure and we know where things need to be , so it's like a big filing system, we are happy that things are stored away and there is no password on the company so nobody can create private data so everybody has access to the whole lot , its important I think that flexibility

Sonia: what about your distribution list? How does that work? Is there anyone in charge of sending information around?

Architect: Technically the project architect for particular project has authority to issue information ideally he should check everything before it leaves the office they should be created and checked sometimes that doesn't happen but that's the problem but genuinely the proper procedure is to have a drawing or a piece of document created and recorded and then issued, we have register all our documents so we know with every project there are 5 or 10 people that it goes to so we have got to check that and issue it and then keep a record in the data base and actually we still print a paper copy to say this drawing went to this people on that date and because it's quite important, when you get them to sign it somebody will say we have destroyed it looks like it's out of date we have got to be able to say no we have got all the accurate drawing and you are simply using the old drawing.

Sonia: who does that? Who send all the information out?

Architect: The project architect is a person who would check and issue it but every member of the team and the person who is drawing it would normally be the person who issues it but they should be doing it all in the authority of the project architect.

Sonia: Right, I was going to say, if they send the wrong information out, if they sent it to the right person what would then happen?

Architect: I think the problem is, the good thing is, because we are quite a small company we are actually , we are all architect so we don't have a big hierarchy. So there is not like architect junior architect then a technician and then someone else, we all have relatively similar skills and we all have a similar amount of trust of each other that the information is going to be legible and correct before goes out the door but that's why technically they should be checked and signature before it goes out, sometimes if we have any difficulties with an individual then we start checking things more , to be honest touch wood most of the information tend to be relatively well considered and I think that's because we don't employ technicians or technologies

Sonia: so I am guessing everyone has the authority to send emails?

Architect: Yes.

Sonia: What about if somebody leaves or someone phone in sick and they have a drawing or document saved on their pc?

Architect: It's not their a pc it's on the network, it's on the project

Sonia: so is there a guideline for that or is there a policy? Every company has its own policy and a new project has its own guidelines, but people don't stick to it!

Architect: No, no when I joined the company everybody had a pc and there was no network , so the data was all locked to the pc and it's not possible nowadays you can't function , we now have a central server with a project and all the data and if someone is off the drawings are accessible to everybody else and their emails and we can see what's been going on if we need to , so that's not a problem, if people put thing on the wrong place I don't know what you do about that, expect being careful, people got to work harder

Sonia: do you have a document management in place?

Architect: We have a filing system that files paper and files any digital data that we have sent but we do not have a system for recording, we record documents that come in but it's a separate system but what we are looking at it now is scanning the data that comes so it is in

the same data base, so we can actually put all the incoming and outgoing documents like a joining compartments, so we can check, this was said and that was replied. We don't do that at the moment, so all stuff going out is managed digitally , all stuff coming in is filed , is marked for an action given to the person to deal with and then file it having recorded the action they have taken.
Sonia: so you don't have any version control for your electronic documents?
Architect: Going out yes we have version control because every join or document is recorded and then when it's changed it's given a version number.
Sonia: in terms of email sending, has this every happened that you just copy people in or blind copy people in or if somebody send you an email there is a list of people who have been copied into that email , do you just reply to all?
Architect: No, the procedure in our office is that when you get an email from 5 people then you will, depends what the email is, but generally if it's on a particular project then , if it's a specific topic to do for example the structure of the building then we will reply to the structure engineer who has probably sent us that , and we may choose to copy that the surveyor who is interested in the file , it may cost more but we would not copy it to everybody else because we appreciate that they might not be interested in the information , if an email comes in and it's got , and we do reply we make sure that we switch off the old data because I hate an email that's got 75 bits of different information , an email goes out with just our reply in it and it goes to the people on the distribution list that we think it's appropriate to see that , if you got any doubts you copy it out to the whole team because they can come back and say something about it.
Sonia: what happens if you have a discussion or if you talk to someone over the phone? Do you have to send a confirmation email out?
Architect: It depends what we have said, we have to record it that we have spoken to somebody we use archetype for that it's just a telephone record if then it needs to be recorded formally then you rely on a person to appreciate that it needs to be recorded formally for example if it's a client instruction for us to go and do something it's going to encourage work then we want to record that then we would confirm to the client that we now have an instruction and we are about to send a bill for whatever it is so you rely on individuals who act in it to know if it needs to be formally responded or recorded but every coming in is recorded.
Sonia: ok, if there an issue raised, how would you track it to make sure it has been solved? Especially if it's by email.
Architect: If it's by email , we don't track it at the moment we would have to ,I could see how we could have an audit trail where it monitors who said to who and what, but the system is not set up, so we get a report of particular topic, at the moment we would simply search for that topic in our emails so if it was about ordering tables we take an order of tables and will see but to be fair its quite rare that we need go backwards , we are too busy going forwards, we don't manage emails that well or we don't record it,
Sonia: can I just ask why you are interested in BIM and adopting BIM?
Architect: Because I have drawn drawings in 2 dimensions on tracing papers years ago and that was a long drawing process that was really difficult we have been using computers and CAD since 19984 and as soon as you start using CAD you realise that there is more to it than just 2D drawing. So I think for the last 20 years I have been trying to do it in 3D and trying to use an intelligent model, I think because I was involved fairly early in CAD it has always seemed logical conclusion and the technology the hardware has been able to do it for some time and now the software is always there, looks like that BIM is the next thing that we need to do if we need to survive in business so it's important thing to do
Sonia: so do you think that BIM will have any effect on the communications practices?
Architect: Yes, but not necessarily because everybody in the design team has particular rule and responsibility and particular authority , they all want to make sure their authorities and responsibilities are fully recorded and managed so there still is going to be a standing part so the team want to make sure that they will have recorded of what they have said and what they have done because they are professional and responsible for it so they won't just put it all in BIM and let people take it , they all want to say I have put it in BIM and they want to

make sure the issue information rather than have someone else just dropping into model and take it away because you might be thinking about that it's not finished yet so this idea of , somehow recording communication and decision with the particular of the model is going to be important for while and I suspect for a while it's going to be by generating a piece of paper to leave to somebody , now that piece of paper might be a PDF in an email but I don't think we are going to let everybody to come in and take the model and presume its complete , it's going to be a process of recording the designer , the decision making and then the issue of the information.
Sonia: That is all the questions I have got. I'm going to stop the recorder now.
Architect: No problem.

Transcription –Laing O'Rourke - Design manager + BIM Engineer
Sonia: The recorder is now on, so John could you tell us a little about what you do as a firm and as an individual as well.
BIM Engineer: Laing O'rourke is an engineering firm who you might know them as a contractor and as a large firm and we do all sorts of infrastructure and also other building such as health, education. My role as I'm entitled BIM Engineer, my role is to implement BIM and make it one of our embedded processes for all of our job roles so I need to share knowledge to our employees to make it one of the things they need and use day to day.
Sonia: Do you use email as your main communication tool or are using any extranet sites for sharing files?
BIM Engineer: We use email for day to day communications, general sort of backwards and forwards, meetings. We have a system called Asite which is our document management system. There consultants and sub contractors will put information, drawings, schedules and other building information and then also client information on there. And that is controlled to who can see what, that is online, it can be accessed from anywhere, it is controlled by password. It can also manage the approvals of documents, drawings and that. Obviously we got telephone and mobile communication as well. FTP site, sometimes file sizes are a problem so we use FTP sites like Drop Box.
Sonia: Who manages all these different sites?
BIM Engineer: Email is just emailed by our IT guys. Asite is an external company but we have our champions of it, we have document controllers who look after each site or a number of sites. So they control who got access individually, Drop box and FTP sites generally come from consultants. I don't know how they are managed, we don't have a FTP site ourselves but we often receive things from others.
Sonia: The telephone communication, how do you keep a record of it?
BIM Engineer: If it is specific and it needs to be confirmed, it would be usually confirmed on an email, to confirm our previous discussion and date it. There are a lot of conversations that don't get confirmed.
Sonia: if the client comes to you and says they want to change something, how would you let everybody else know about that change/request?
BIM Engineer: If there is a client change that would have to go through the appropriate system for that contract. So that might be as a change it would have to be written confirmation.
Sonia: confirmation by email?
BIM Engineer: It depends how big it would be. I'm not 100% sure but you can probably get small things on email but it would have to be as a change and that would have to go through stages of approval. Preferably it would have to be approved before other people have seen it, it depends how strict that is.
Sonia: These extranet sites, do you get notifications?
BIM Engineer: you can, you can choose if some email notifications, if the person who puts the document on can highlight individuals to give them immediate email confirmation to say something is on there. Or you can get a daily update through email which says how many actions you have outstanding and for what project.
Sonia: Do you think you deal with too many emails a day?

BIM Engineer: Yes probably. They just come thick and fast and sometimes it takes a while to catch up.
Sonia: What about your archival system? Any formal support or policy?
BIM Engineer: I'm currently struggling with that and I don't really know if there is a strict policy. As far as I understand we have swapped over to an exchange server which is suppose to improve things. With my role, I receive large emails and it gets full quickly. And I get emails daily so size is a big problem.
Sonia: These extranet sites, they are all centralised hubs, who has the ownership of that?
BIM Engineer: We have a subscription with Asite. So we have a framework deal with Asite, the company, and then that will allow us to have a cost on for every project or every user and it has reasonably changed how it is subscribed to. It used to be where every project would have a cost but it is actually users now. So you have internal and external users. So it is another company, it is Asite who has ownership.
Sonia: What about the data that gets put on there?
BIM Engineer: each person who puts stuff on there is responsible for what they put on there. Consultants work for us so that would become our design and liability in design and build contract. So the design in the ownership of those documents is ours but we hire consultants to produce them
Sonia: what about your distribution list?
BIM Engineer: Project wise various different scenarios I suppose. On sites they have contact and distribution lists on there, a paper copy or an excel format. Centrally we have email accounts which have distribution lists for the northern region. Distribution lists on Asite can be configured for the projects. So it can be done for a particular package so it might be steel work package so the people who have been grouped together for documents which will have affects on steel work packaging that will be distributing on that way. Or you can do them individually by company.
Sonia: who is in charge of sending information out? The distribution list?
BIM Engineer: The document controllers on projects tend to sort out the Asite, so extranet information that should be distributed.
Sonia: has it ever happened that the wrong information gets sent out?
BIM Engineer: It probably has, I can't think of a scenario. You tend to get, sometimes you tend to receive more than what you probably need because you get copied in and that could become a problem. And the system is not used or set up correctly and it can really affect it. Because if you get copied in once something has been uploaded so you will get copied in when someone comments on it or approve it and etc. So you can end up with a number of things to clear which is not really for an action. The names tend to be on the system. It could be a lack of knowledge of how to use the system properly. There are trainings available; there are a lot of people to train on large projects.
Sonia: Is there no policy for copying for people in?
BIM Engineer: Not that I know of.
Sonia: Do you ever Blind Copy people in?
I tend not to. I CC people in for the purpose of, on an email particularly, I will send it to people I think I should or receive respond to. I CC to people who should be aware of what is going on. But I don't think I need a response from so I tend to not BCC people in.
Sonia: Are using Microsoft Outlook for your inbox?
BIM Engineer: Yeah.
Sonia: Does everyone have authority to send emails?
BIM Engineer: As far as I'm aware yes. I mean staff will generally have a computer as far as I know. If you have a computer you get an email address and you can send emails.
Sonia: These extranet sites, do you use the same one for every project?
BIM Engineer: We have our own preference. But it might be a client request that we use a system of their choice in which case we have to use theirs. There are instances where we will use other similar things like BIW or other ones.
Sonia: If somebody, especially with an important role, if they leave the company what happens then?

BIM Engineer: as far as I know, if they have a laptop, the laptop goes to IT and it will be dealt from there, depends on what circumstances they left. From the hand over period to whoever was going to take over their role but the machine would go to IT to sort out the data.
Sonia: Is there a policy where you have to deal with one issue per email? With a subject heading related to that issue.
BIM Engineer: I don't know of a policy like that, we normally get a number of bullet points of different things related to the same project. We don't separate them in to individual emails. The subject heading, I would suggest to broad the subject heading to cover all the issues. I don't really know.
Sonia: You are a BIM Engineer. Do you think BIM is going to have an effect on the way people are communicating?
BIM Engineer: I think we used to deal with RFI's. We work in a working progress space with BIM. So now we don't necessarily need information to be issued, information issuing is changing in a way so design managers who lead the design team will, they can see that things are being done without having necessarily drawings to be issues on to Asite. Because we can see the BIM models being produced. Because of that we should be able to solve more problems earlier on. In a working processes, sort of fluid before we have to issue things and because of that we should get more issues ironed out, less RFI's, less drawing issues because we are getting them sorted out in a digital format without people have to issue things for people to check them and send back. What we tend to do we get the model issued, we build the models, we review them as a team in various different ways, depending on who got what software and from there people can go away, review the actions and we can redline on the model so notes are recorded in there and they can go back to those systems and review what we said and work away on it and come back together again and see where we are going. So I think it does change the way people are communicating. I think some people do suggest you see less RFI's and less drawing.
Sonia: so that is emails, less information uploaded on extranet sites.
BIM Engineer: So in theory with the model you have all the information to hand. It might not be the case because of some technical issues, different software but if you a consultant have the other consultant's model. In theory they can see everything the other consultant has. So something where they have had to in the old working ways, you might have a set of plans and sections but the consultants want to see another section which doesn't exit so they have to RFI whereby if they have the model they can see it themselves. So we would see a change there.
Sonia: So it means a better collaboration.
BIM Engineer: Yeah.
Sonia: This is all the questions I've got.
BIM Engineer: Ok.

- Some people treat email as a task. They come in turn their laptop on check their emails only, turn their laptop off go back on site and come back again after a few hours to check them again.
- In our company some managers say; do not check your emails till 4pm. If it is something urgent they will ring you and if it needs recording then email it.
- The document controller guy has the role of information flow. He controls the documents on extranet sites whether internally or coming from outside and directs it to the right person. On bigger projects we might have a number of document controllers.
- Distribution lists and packages are based on Work Breakdown Structure or their procurement method.
- If I'm travelling I wouldn't be able to check my emails so it is no use emailing me.

Transcription – South Tyneside Homes – Project Manager
Sonia: Are you working for South Tyneside Council which is clients?

STH: I work for the client team within a social housing group.
Sonia: Do you have extranet or you use email as your main communication tool?
STH: main communication is email or we get hard copies sent.
Sonia: So you don't have extranets.
STH: No.
Sonia: So, if you are sending things by email, how do you manage them? Version control?
STH: Most of it is like scanned and put on to the computer and we transfer it as an attachment. Obviously they are downsized on the computer through email and then we can Bluetooth them to the printers if we need to enlarge them to the original size.
Sonia: what is the common procurement method?
STH: It is mostly Design and Build dealing with contractors. A lot of the building work is done in house. We got a set of architects that we use if we need to within the company that do drawings.
Sonia: Do you deal with too many emails a day?
STH: Not so much too many emails. Too many stupid emails asking you silly questions. But I deal with a lot of emails a day sometimes up to 30 and 40 emails a day if I sift out all the stupid ones it is not as bad.
Sonia: if there is an issue raised or you come across something that you need to let everybody else know, how do you do it?
STH: It depends how many people is in the office at the time, if the office is full and you can't hear yourself talk, if we need everybody to find out we send out what we call an All staff email. We have got to write the email that goes to our communication team, they sift through it to say that there is nothing offensive or inappropriate.
Sonia: Do you do that for all the email?
STH: Only when it goes as a all staff email that we have to get it checked that there is nothing offensive in it.
Sonia: What if you want to send it externally?
STH: we just send it as an issue in an email. We can include them in an all staff email or we can single them out.
Sonia: How do you track it to make sure it is solved?
STH: Well, we can put a track on the email itself to say that he has opened it and he has read it. We always put in that we like a response and you can put it high importance. You need to send that straight away and you need a response within 24 hours.
Sonia: Is there any formal support or policy for archival?
STH: We have got what we call the F drive, if there is anything that needs keeping where anybody can access it to get information in the future it goes on the F drive. Now all staff or 90% of staff got access to the F drive.
Sonia: If you haven't got an extranet do you have a centralised server so everyone can have access to all updated version?
STH: Yeah, it is the main server at South Shields town hall.
Sonia: So everything is on there for everyone to have access to it.
STH: Yeah, any forms, policies that we need.
Sonia: Have you got a distribution list?
STH: It is called, everybody's email address is on the computer system so if you go to send email, it will bring every name and you put the names in. If you know the email address of the person you just type it in. And you pick out which ones you want to send it to.
Sonia: So you decide who to send it to? Or somebody tasks you who to send it to?
STH: Personally I would just pick out who I need to send it to unless I'm told we need you to send that copy to this person.
Sonia: How do you know who to send it to?
STH: By experience really.
Sonia: Do you also get time limit for response?
STH: Sometimes you do, mainly the more professional ones like the surveyors or project managers say to you can I have a response to this within 48 hours? Or as quick as possible? And 9 out of 10 I can give them the response before they actually wanted.
Sonia: Do you have a document controller person who is in charge of information flow?

STH: I don't think we do, I think it is left up to individuals.
Sonia: Is it ever happened that somebody sends the wrong information out?
STH: They have sent it to the wrong person but up to date information.
Sonia: Any huge implications?
STH: No because normally you get a response back from this person, sorry but I think this email was meant for somebody else. Sometimes you realise yourself that you sent it to the wrong person.
Sonia: How do you record your telephone discussions? Confirmation Email?
STH: Not normally. What we normally do, I have a book and if I go on site I carry it with me just in case I have a conversation with somebody and this needs to be recorded, I just take little notes. So I can remember it later on if I need to send an email to somebody about that conversation.
Sonia: But how can you prove about what has been said, especially by the other person?
STH: You cannot. When you send an email out you get it in your sent items so you have a receipt to prove that.
Sonia: Have you got an audit trail?
STH: All emails that get sent, our central IT guys can access all the emails. There is an audit trail in person but I don't think there is a person who checks every individual email.
Sonia: Is there a policy or a QA stating that you can't copy people in? Or blind people in?
STH: It is not that you cannot copy them in; our company tends to try not to copy people in. But there is times where you have to.
Sonia: why not copy people in?
STH: Because they reckon it is unnecessary emails that people have to open. But if is something that the person needs to be aware of you have to copy them in.
Sonia: What software are you using for your email?
STH: Outlook.
Sonia: Does everyone have authority to send emails?
STH: If you have an email address then yes. Some people work for the company who do not have access to emails. Like the people who build houses.
Sonia: What happens if somebody leaves?
STH: All their stuff get stored and there is only our IT team who can access unless they give their email stuff to other people.
Sonia: That is all the questions I have got. Thanks.
STH: No problems.

Transcription – Contractor - Planner
Sonia: The recorder is on and recording now.
Planner: Ok.
Sonia: You said you worked in industry for quite a while, which part of the project procurement team did you work for?
Planner: Ok. My background is prior to my current job; I worked within construction industry for a main contractor, the guys who actually build the works if you like. I spent 6 years with one major contractor and further 2 years with another contractor before that. So I was a planner which is the person who is responsible for looking after all the time related elements on a project, the person who produces the program at work and where the quantity surveyor might look after the money, I was the guy who looked after the time and reported it to the project manager.
Sonia: How did you use to deal with all the information and all the drawings? Did you use to get them through email? Did you use extranets? Intranets?
Planner: Over the course of different projects, we did different things. If I start talking about roundabout year 2000 we were still using dial up internet on site. I don't know if you can remember that and how slow it used to be and when we were using dial up they started trying to introduce project extranets in to one of the jobs I was on, on a £43million job in London and the client wanted to use an extranet and we used something called project net which I had used before. I worked in the united state for a year as well and we used that

system before. And that was a system where they would host information onto the extranet where the entire team could retrieve it. So the contractor including myself, the subcontractors could get it if you had certain access rights. Different jobs of different values, so you might get a job that is £6 million and the client won't be willing to spend the money to have a project extranet on that size of job. Couple of jobs I have used them where there have been larger jobs where the client wants to use them. When he hasn't had a preference the contractor has decided not to use them because they don't see the benefits spending the money and a lot of the time information such as drawings has been emailed.
Sonia: So does that extranet only get used for this particular project?
Planner: The example I'm giving you was just used for that particular project within the company. We used bigger extranet systems, same company, we had 4projects which is one of the biggest ones, we also used BIW another big one. There was never any consistency from one project to a next project. The reason for that is, we actually searched them and say which is the best one, I wasn't part of that team, and we looked at the ones we wanted to use. We wanted to use 4projects or BIW. But at the end of the day the client was the person who was paying the wages and if the client and his consultants had a preference for using a certain system says BIW we just went with what they wanted. We weren't in a position to dictate to the client our preferred system. Does that make sense?
Sonia: Yes. So really it was up to the client and not up to you what you want to go with in terms of the collaborative system and what you wanted to use.
Planner: Correct. The companies I worked for were fairly forward thinking and they would have had systems they preferred to use but likewise if it was a smaller job for a lower value they wouldn't want to use any and they would just rely upon emailed information. I think obviously PDFs have been round for quite a while now but I can remember what used to happen be that they used to upload DWF. DWG.files. It was only really when people started to catch on about emailing PDF files that transferring information via email caught on because the file size was so big otherwise. So the last job I worked on actually, the contractor had a system called, well we called it EDMS, electronic document management system, but I think something like gateway was the provider. We were quite happy with that. It was an internal system that the company owned but we did give access to our consultants to upload drawings and things and that worked quite well for design and build projects. For design and build projects when the consultants or subcontractors to us we had them tied in to use our system. On traditional projects where the client team and the consultant team, it was often dictated on what system to use.
Sonia: when you had your extranets, would you just share files and drawings? Was it only used to upload and share files or did you use it to assign tasks, approval/rejection system or calendars?
Planner: Again I've seen it done a number of ways and I can talk you through different ways. The most efficient way from a contactor's point of view that I've seen it done was the last version the EDMS. The EDMS it was basically used as a dumping ground for the drawings. Ok? And all of the revisions of drawing, if you imagine you had an original drawing and it got revised you could put that file on top of it and if you could right click on the file and you can see previous versions.
Sonia: So it had version control.
Planner: So it had version control. Rather than having, but it looked like a windows file management folder, so it didn't have the apparent of an extranet so it looked look something you open a folder, you would go in to that and you would have different folders with different revisions, one drawing one and you can right click on that and pull up versions. So in that respect it was a dumping ground for documents, drawings, specs and things like that but we could access all previous revisions straight away. However what we used to often do was to just open an email with outlook and distribute it via email. So even though we had this storage electronic document management system for drawing we still distributed via email. The other way when we used 4project and things like that, we found, well I found them to be very onerous so when you would login everyday there would be like a check in and it would tell you how many issues were unresolved and it would say since you last login 30 new drawings have been uploaded and you have16 issues that are unresolved. To be

honest with you it was more like a bind runes than anything else you knew what was really important. Because these didn’t really prioritize these issues. They just had them like; they had 3 new documents that you hadn’t looked at. You might have logged in to check something else; this is part of a problem with email. You might be going to your email to check something and you lose track of what you are trying to check because 50 new emails pop up or 6 new issues pop up so I find all of that to be bind runes and it was almost trying to be too clever. It was trying to get you to be held accountable: you haven’t yet read this drawing. Do you know what, I might not need to read this drawing just now? I might be getting on with more important things. So I like the idea of shared project calendars, I don’t think they caught on, the task list, again people have their own preferred ways. I think the big win with these systems is document control and versions and stuff like that.
Sonia: Did you use to get notifications through email or was it only when you logged in that you could see them?
Planner: We did. You could set them up so they would send you notifications.
Sonia: So there was still information overload?
Planner: You could set it up so you would get it via email. All I used to do was to create a folder on windows, get them set a task up to direct notifications to that notification folder and never read them.
Sonia: So you easily ignore them.
Planner: I just ignore them, deleted them or block them. Because we knew what the important issues were on the job. It is like someone tells you, you haven’t done this or that.
Sonia: What about someone has a request or question about something? How did you use to do that? By email or phone?
Planner: you are dealing with people at the end of the day. So, obviously a lot of the time, it would be face-face communication or on the telephone. Generally, there are issues that arise on a project, something becomes a problem, and you know about it because either your manager is telling you or you receive a phone call or someone wants to have a meeting about it. If something is that important they are going to try and communicate with you in a format other than sending you a notification. You get what I’m saying? That’s where the prioritization comes from. There are things like RFI’s. Are you familiar with these terms?
Sonia: Yeah.
Planner: Large part of my job was dealing with RFI’s and taking requests for information from subcontractors and consultants and redirecting them to the right party. Because contractually we might have not been in a position to solve them but we certainly had to control the information. So what would generally happen is somebody would come and say there is a problem with this x, y and z. And I would say ok, I will start investigating it. I will ask the question but I will put it in RFI so we can track it and monitor it. The problem was getting solved before the RFI was even raised but we still had to go through the formal process of documenting this information and communicating it.
Sonia: You know how you mentioned, for smaller projects you used to use email as a main communication tool. How did you deal with things like version control? Giving access to the latest version? If anything got changed?
Planner: A lot of it depends upon the procurement strategy that was used. A lot of my jobs were design and build jobs. So, you think that because it is a smaller job there will be less information but you still going to have x amount of drawings. The value of work is smaller but you still might have 30 drawings showing you the floor hands the room data sheet. Same amount of information just smaller value. It was just via email and basically using windows structure. Just clever filing. A lot of companies either don’t have a set way of filing the information or try to impose a structure upon you that might not be the most efficient way as well. There was always this kind of tension between myself or someone like me identifying a better way to file the information and being told it is company policy. Here is a good example; I know it is not for sharing information. We used to take progress photographs all the time. So I would go out with my camera with the date stamp on, take 200 photos a week and I would just file them in week order. Week 1, week 2,... and that was sensible because if anything happened I would go to week 5 folder . You have to set on

monthly basis because ..I know I'm going off topic, I'm trying to say there different ways of structures.
Sonia: I was just going to ask you; were there any published guidelines for using emails? For communications?
Planner: I think within the first company I was at, they were a bit more structured. There were procedures in place. But at the same time, what I'm getting at is just because they have written a procedure it doesn't mean that is the best way of doing things. I kind of did what worked. Often it was improvement of they were trying to get you to do.
Sonia: You totally ignored the guidelines?
Planner: They are important because if people don't understand what they are supposed to be doing it helps them to put them on the right track. But if you have innovation and better way of doing things, often the company would say you can't do that and you have to do it this way. Bit we are doing it the better way, the more efficient way. That was my personal stance on things.
Sonia: Really, the culture within the organisation was not strong enough? It wasn't too restricted. Just so they can get to people work they want them to work.
Planner: The first company, they definitely had a type of culture where they had set procedures for everything. It is over killed though with procedures. The second one would just let you get on with it and do what worked which for someone like myself, I like that but I can imagine they wouldn't like that. I guess it comes down to individual's preferences at the end of the day.
Sonia: people have different behaviours and attitudes towards different things. Was there someone in charge of the information ownerships? Who was in charge of it? Did anybody own all the information that was going round? What was the responsibility like?
Planner: From a contractor's point of view?
Sonia: For instance, you know, if you made a mistake and sent the wrong information out, who would be in charge?
Planner: If we are talking about an individual project it would be the project manager. So remember I'm telling you everything from a contractor bias here.
Sonia: So would you have you own project manager?
Planner: Yes.
Sonia: Who deals with the client project manager, is that how it works?
Planner: Yes, that's how it works. Often contactors have a senior site manager or a construction manager who they call a project manager and you have got the employer's agent who likes calling themselves a project manager. That's my bias coming through there. If I talk about the construction project manager, what they often do is they delegate to appropriate people. So I used to deal with a lot of information distribution with my job and he would just let me get on with doing it. And you are saying if I did it wrong it would be up to him. But it is one of these jobs where it gets delegated to a lower lever then a lower level again and often you get people who for contractors, you only have so many resources on site. You might have a project manager, a quantity surveyor or two, a planner, two or three site managers and a secretary and often it would be the secretary who would end up doing the day to day chose of distributing the information, whether its hard copy or electronic. Distributing information, filing the information, bringing issues to the project manager, brining correspondence to the project manager and these guys are so old schooled, they'll not read their emails, they will ask for a hard copy of the email and then they'll say , oh send this to this person. Within my role was often I would manage the distribution of information that normally the secretary do it but I would put the though in to it, you need to distribute it to this person, make sure so and so gets a copy of that and make sure you file the email probably so we can find it later on and the attachments.
Sonia: So there must been lots of difficulty in managing and coordinating the information?
Planner: Yes.
Sonia: Was that the same when you used the extranets? Or any other collaborating tools?
Planner: What people used to use them for from the consultant side particularly was, we issued that information; it's on 4project, right? So we would be asking for a particular piece of information. Let's say the fire drawings. We would say we need the fire drawings and we

would come to the client meetings. We say we put them on 4projects; they have been on there for a week. They might not have attached them to distribution sheet or like notification, whatever you want to call it. So people used to use them as a tool to hide behind. We started doing it as well. Like the monthly progress meeting, the day of the meeting, if we had the meeting at 12, at 8 in the morning the client would want the program before hand to review it. I would get there and I would say it is on BIW, I had only put it on this morning and but say it has been there for a week. It became like cat and mouse game rather than collaborating. I know that is not the right spirit but that's what it happens.
Sonia: That's what I'm trying to find out. Did you used to use CAD and 2D drawings? Have you ever used Revit? 3D modelling?
Planner: I'm aware of it. All the drawings we received and distributed were 2D Cad drawings. I'm much more aware of Revit, coming to this environment and seeing it all the time. But from a contractor point of it we were dealing with 2D drawings or a few 3D images. We certainly weren't at the moment of time or at least up until a year ago the majority I would say they weren't aware of BIM modelling.
Sonia: how familiar are you with BIM? What do you think BIM is?
Well, when I was in industry we were aware that there was a tool that could produce 3D images and help with clash detection. That's what we thought we knew about it. It could help you plan in future and avoid clash detection. We thought what good is that? We didn't realise it was a live model. We just thought it was 3D representation of a particular issues or something fancy to show the client when you did the work. In industry we weren't aware of it but I am aware of it now. However there are limitations.
Sonia: Do you think, if you were still in industry if your organisation adopted BIM, would you say that it would make things much easier? In terms of communication and collaboration?
Planner: I would definitely say that. I am relying upon the construction industry, but unfortunately because of the way the industry works, because there is low profit margin on these jobs, really construction companies are set up to turn over money. They get money from the client, hold on to it as long as possible before paying it out. The profit margins are quite low. Regardless which the industry considers itself to be a low profit industry and they are very hesitance to pay out money for things that they consider to be, you know, what I'm trying to say here? Some sites won't have any broadband or anything like that still. Even though we communicate via email every day, some sites you only work on the site, you have to justify why you need a wireless on your laptop. Even though it is still to do with communication and information is the life blood of the project, they are not willing to spend any money. You get what I'm saying?
Sonia: Yes.
Planner: it could be a massive help, it could revolutionaries the way things are built. It will, in due time. This period now, it is like the period of dial up. Why should we invest in broadband? I'm assuming that's what is happening. They'll know about it. They want to say who uses BIM but when it comes to the crunch spend as little as possible to make as money as possible.
Sonia: One more question, when using the extranets, obviously not everyone is too keen on using computers and new technologies? Was there anyone who would resist against the change using a new technology and not doing the traditional ways? And they would totally ignore it?
Planner: Yes, lots of people.
Sonia: How did you deal with it?
Planner: It is strange because when I graduated I was keen to push technology and I was able to do things earlier with my career because I was technology savvy. Yeah? The industry is full of, I mean I'm am picking on site managers here they are 50 year old guys who have got away without using computers all their career, they got to this point they don't really want to start using it now. It is like what I said about printing out the emails to read. It is the same things with drawings, we have the computer screens, we can see the drawings on them but people won't read them, they'll print them out to read in hard copy which is fine if you want to measure something. But if you need to open them up, the great thing that

4project had was , and it was never really used, was the opportunity to mark up on the screen with a red pen any areas that needed to be changed and save that version. People didn't adopt it. They used to print it in hard copy, mark it up with a red pen then get somebody to scan in the drawing to file it on there which is crazy. Even now, unfortunately I print things out to read, because I'm used to it. Site managers, yes they think they can get away without doing it, other people know technology is a part of everyday thing. What was the question there again?
Sonia: I was just wondering if people are, because people resist against change, especially if it is a new technology. Sometimes these extranets and EDMS are complicated to use and people not want to use them.
Planner: They resist change, they make flipping comments. A part of the problem is that technology change is so fast, there is always something new happening. But I have been in training session where they try and train these people and they fall asleep because they are not used to sitting in a class for an hour listening to someone. (Explanation about SNAG). It is to walk around and to make a list. It is like a list, making sure everything as it should be. The age old thing is to walk round and make a list. You make a list. You might have 50 different snags, different companies. They'll give it to the secretary; she'll then look at, there is 10 snags for the painters, there is 10 snags for the joiners. She needs to the disseminate the information and send out letters. We trialled something where it was a PDA, handheld PDA and it could walk round various rooms, they would have the drawings on the PDA, if there was a scratch there, they would get a pen and put it on the drawing and synch it when they went back to the office and send it to that sub-contractor. They wouldn't use these kits. And now you have a big camp between 50-60 year old and 20-30 year old site managers.
Sonia: The reason why I'm asking is because BIM is a new technology and they are trying to push it in to industry. There is going to be a lot of people who are not going to be happy using Revit. It is not a difficult tool to use mind, but it is new technology. They might have some problems with file transfer, ownership and etc. I'm sure there are going to be lots of people not wanting to use it.
Planner: what they'll do is, if I can envisage a situation where we got capabilities for BIM on site and there are 3, 4 people who can use the model on site. What would happen with the managers on site, they'll come and ask a query and they'll say there is a problem with this interface here; can we have a look at it to resolve it? The guy brings the model to have a look, the managers say can you print it out so we can take it on site and build it? That is what is going to happen because they are used to print outs. They would want a 2D drawing print out. They'll not have access to a computer on site so it'll be adopted by clients, by consultants, by forward thinking contractors and it is the same when extranets happened on site. You end up running two systems. When I used to work, this is what I used to do, you end up running a system that client wants, the extranets, all the project information between consultants, client and contractor is electronic. But at the same time I was also in parallel running a paper base system because the guys on sites want drawings and things like that. So it is great for the client, it is not good for the guys managing the system they have to do everything twice. However they will adopt, the time will move on. At the minute we are in a situation where the experienced people, people are scared to change.
Sonia: I think that's it.
Planner: Good, I hope it was useful.
Sonia: This is all the questions I've got; I'm going to stop the recorder now.
Planner: Ok.

Transcription – Turner and Towns – Quantity Surveyor

Sonia: So Dave could you tell us little about what you use to do when you were in industry?
Quantity Surveyor: I was a senior cost and commercial manager for Turner and Town working from the Newcastle office mainly but one of my subject areas was that I was a

member of the construction service excellence group within Turn and Town looking at ways we could better use technology to prove efficiencies those kind of things as well also I had a research remade as well as a technical remade.
Sonia: Right, did you sort of use to deal with information via email or did you actually have an extranet or interact?
Quantity Surveyor: Frequently yeah, both, Interestingly towards the end of my career at Turner and Town working at energy oil and gas industry, so I have got the experience of both sides of the coin of the traditional contraction methodology and also model based design, because we use models to design the plants , but yes use to handle information both in drawing form, physical paper less so these days, mostly electronily forms of drawingcommunications specification, information those kind of things and also we would use both client extranet and intranet industry standard ones and also direct communication of information.
Sonia: So this Extranet that you are talking about, did they use to vary from project to project
Quantity Surveyor: Could do yeah, If you had a client , a specific one, so, Tesco had a database called my property, on my property they would put all the information about a particular project on there in an electronic format, very much like a 4project, things that used, built, based, and fort projects and all these other systems and then the point where that we would go from what we would describe as deco rational to operational although we took the store from being actually commission store and get it running and get customers nil the information that we transcribed cross to an operational file for that store so we could use the project data going into actual use data at that point.
Sonia: So these extranet, did you to sort of use to just use them for uploading information and drawings?
Quantity Surveyor: and downloads, both, it was two directional, we use to put our recording notes on there and take information from it
Sonia: So you didn't use to use any other functionality like calendars, tasks?
Quantity Surveyor: We did yes, we had all of that, used all of that.
Sonia: So did you use to get notifications through emails?
Quantity Surveyor: used to get email notifications, which is exceptionally irritating way of doing business, personally I'd rather use something like an RSS Feed or something like that to actually aggregate it.

Sonia: Why don't you like the notifications what's the meaning about it?
Quantity Surveyor: The difficulty with the email is , email is dependent on the sitting screen looking at it, and within most industries, this is my personal opinion, where we have gone from a project management communication cultures based around people, based around picking the phone up or actually talking to your consultant or to your client, to the assumption and the classic word , I sent you an email, but I sent you an email yesterday why haven't you done it, yesterday I was on the train from Paris to London and then from London took a plain to Edinburgh and then from Edinburgh to Aberdeen and from Aberdeen back to Paris, I wasn't connected to my email, and the problem with the email is always this assumption once you have sent it, the other person has read understood it correctly and also being able to action it
Sonia: But don't you think people are using email because its more formal and they wasn't to have evidence of you know when they turn around and say I told you this before and they want to prove it , there is evidence.
Quantity Surveyor: I think that's a really bad approach, if you are looking how to make people work in I think it was oh I can't remember his name, was a colleague of Luis Suarez from IBM who said that emails placement technology are going to die, it completely silo based method of communications unless you wish to broadcast to all, the issue that I have with it is that in legal terms, as a quantity surveyor, contract legal statement those kind of stuff, claims, constructions issues where legal and contracts get involved, a lot of people do not realise an email carries the same sort of legal way as writing a letter, they all thing that a letter is a formal thing like a big warning shot whereas an email it's just like......They don't

actually realise that the 2 carry the same way, my view is you shouldn't write something in an email that you wouldn't prepare to put into a letter, and I think what people regarded as, as an informal method of communication with formal influence, my view with email is that I would never send anything by email unless I was happy with it, you know I would not personally send a one liner, I don't regard that as being an effective method of communication. Project management by emailing is horrific.

Sonia: did you have any difficulties in terms of co-ordination and managing information when you were working obviously?

Quantity Surveyor: Frequently,

Sonia: How was the information managed and coordinated?

Quantity Surveyor: Badly usually, it depends on what you ...

Sonia: Like for instance one of the things is version controlling in terms of people updating drawings and documents.

Quantity Surveyor: Version Control is horrific, it's always a major majormajor problem, i don't know a lot of people have said, we use to KPI again at Tesco one of my main clients, we had a KPI and store designers, and store designers were only allowed to once the plan had been fixed which is a thing we call retail plan which lays out the shop floor it shows where everything needs to go , and it's a , it's a plan view with all the shielding, you can see it from the above, you can see where everything going to go, and they are all colour coded, the different lines depending if its hard lines. They are the KPIs that once they have been signed off by the store management group , its fixed, they are only allowed to change the drawing 3 times, after that beyond that its almost just a punitive measure, it's too much change. Because it's a signed off plan you are now procuring ,ordering, buying things, starting to lay the store outside to rebuild things, to make that plan happen, if you change it more than 3 times it causes major problem to the shop floor teams that are trying to this while you keeping the store open over night working, sectional working, sectioning part of the store, what we use to find was, because they were KPIs on 3 hits, 3 strikes and you are out, you would get like a revision C, Revision D, Revision E, Revision E Revision E Revision E, so in drawing register format there was no actual change, but you could have 4, or 5 different versions of version E that were actually different, and a lot of the time you wouldn't know which one you were working of. When I worked as a contractor for CORILION we use to build hospitals and major claim at a large hospital site down south not sure which one, but we had 14000 drawing revisions to track on one ward block, now it's absolutely impossible to co-ordinate that.

Sonia: Was there anyone in charge, like was there anyone responsible?

Quantity Surveyor: yes, you have document control on both sides generally, when you are in commercial, in consultancy you manage your own and that's where often systems like 4projects Tesco's my properties are invaluable because you can get the right drawing information and you can see the history of it electronically you are not relying on it. One of the problems being a cost consultant is, although you are part of the design team you are not actually a design function generally, we can't function designers, we are not allowed to, which means you tend to be an end of line user so I , the information I would get is always as a issue not as its developed, so any I see change aspartic, I see change in peaks so I might see a drawing 2 weeks later a revised drawing , 2 weeks later a revised drawing , I may not actually see the development process between or a get chance to be able to understand the changes. Or you won't be able to contribute to change that, and that's a major issue for us as end of line users, we are not often actively involved in design change, quite often, but we are expected to act for it immediately.

Sonia: right, so is that design coming from the design team?

Quantity Surveyor: yeah, architect or the engineer or who ever....

Sonia: did they send these drawings in 3D formats or are they just drawing in terms of piece of paper drawing or 2D drawings?

Quantity Surveyor: in Turner and Town we were very much to the AutoCAD we used to get most of the stuff in, we were expected to work electronically where we could, what we often found was the quantity surveyor didn't really have much BIM capability or 3D capability and couldn't work from a model. So we were always the end of the line we were asking can you send me a section an elevation and a 2D floor plan from a 3D model and some cases, generally most of the information was in 2 dimensions,

Sonia: So you are familiar with BIM? What's your perception, what do you think BIM is?

Quantity Surveyor: it's a very wide question, as a design tool as an overall...

Sonia: just an overall definition what BIM is?

Quantity Surveyor: Building Information Modelling basically, it's an ability to handle and process a lot of information about a building and just its orientation or its 3D structure or sign it actually be able to take objects within that building and assign them information so goes beyond sketch design and actually goes into more holistic approach of getting everything together. The downside of an early stage of the design is quite problematic, because you don't actually have a lot to go on, so from my point of view cost consultant traditional ways of working don't work too well in the BIM environment.

Sonia: What do you mean by you not having too much to go with it? I thought it's better to have a 3D model! Like have access to all information at early stages brings all the decision making forward

Quantity Surveyor: yes it does, but from the cost estimating view which is the cost consultant come from, out tradition tools techniques don't translate particular with 3D world. Our cost development line follows the traditional RIBAstyle methods of design process, so RIBA stages are A-H. My view is that does not necessarily translate into BIM particularly well, how we measure and quantify buildings does not necessarily translate well although we can derive accurate quantity from the model. We are still a little of bit of error on to how we actually process and deal with that, so it's difficult to recon silo it to how we do business at the moment .

Sonia: did you have any difficulties using BIM in terms of obviously the file transfer, you would have different file format?

Quantity Surveyor: it's too many file formats, too many property standards not enough common standards,

Sonia: so did you used to use any of the data?

Quantity Surveyor: yeah, in my experience which is fairly limited of cost managing using bin I understand more about it now , but the primary software like ECUS that costs managers to interpret it wouldn't accept an IFS or a RVT file, we would accept what was called a DWXF file I believe, there is a DWXF and DWXG which are vector driven rather than object driven, so the limitations on our software was , it was driving a visual engine rather than actually giving us the object data from a proper database type, from a proper mark languages.

Sonia: So you have worked with 2D and 3D modelling was there any difference in terms of communicating round these models? When you move from 2D to 3D, was there any changes in terms of communication, would you get more information request at early stages, was it the same process?

Quantity Surveyor: well from my end I am usually the one who is generating the information request, so I am an end user, I am not part of the design team, I can't actually have or generate anything on the model, and I am not and should do so.

Sonia: would the model, obviously the 3d modules would it help you, does it raise more questions because you can see the model rather than seeing a 2D drawing?

Quantity Surveyor: it makes it easier to interpret the intent, so from my point of view looking at something in terms of its cost per meter square or its costing in build being able to actually see it as such and understand floor ceiling, understand potential clash, understand frame intrusion, those kind of things are quite useful for me on the other side our process is a designed operate without level of data, so sometimes is really difficult to reckon siloon our early stage processes with a different method of design because, when KUS which is not rally equipped to well to operate in this world at the moment, that's due to the fact that we tend to be an industry that doesn't early adopt technology, we tend to be one of consultancy groups that sits behind, we are almost looking at for everyone consultant, one architecture consultant I would come across who is using BIM or they maybe 10 who aren't.

Sonia: Was there a problem with ownership?

Quantity Surveyor: Ownership of the model, absolutely horrific, the contractual argument about who owns the model.
Sonia: as a client you don't own the model?
Quantity Surveyor: No, well yes or no that's what the contractual argument was all about , generally you would expect to as the client but there was a lot of , there is 2 different ways of looking at the ownership of the model, there is an ownership of the intellectual of property and copyright of the model and there is the ownership of who actually owns it in terms of who has the race who actually is the person who manages it and that's a problem where the industry shouldn't be squabbling about, this is where the architect own it, does project manager owns the model and let people use it ? Does the architect own it and let people in? Is it stricter engineer who has to use it? so who actually both in terms of IP (Intellectual Property) owns that data and information I would argue it should be the client at the end of the process because if you commission the piece of art you would expect to own thing at the end of the deal , you wouldn't expect the architect to say hang on, he can't take photographs of that because I own that image rights , you don't expect that, but from a design team point of view who actually owns it in terms of its operation maintenance etc. When the contractor comes on board and does he hand it over to them because they are the ones who are actually building it? So who takes ownership of this object both in terms of it and also in terms of its upkeep, its feeding, cleanings and its maintenance, in terms of a model that is actually looking after it? It is a major problem at the moment because we are not set up to operate team that way. I think one of the other problems that we got is that unless you set store allow to day one and actually set the standards for everybody to operate on and to enforce that you get dogs breakfast.
Sonia: so obviously you have you 3D model, you have your BIM, doesn't that enhance your job performance in terms of you can just phone the design team up and say right I have made some changes and I know you are the client but I request these changes to be made, if you go to this place at this point you can see where I am actually talking about, isn't that easier? In terms of having a 3d representation?Rather than 2d drawing?
Quantity Surveyor: only if you can drive and interpret the model
Sonia: so doesn't that sort of ease the communication, doesn't that improve the communication?
Quantity Surveyor: it doesn't and it does. It does it in one way and yes you can indicate and area indicate an object, build something around look this room I want to do X ,on the other hand , there's always going to be that difference between a snapshot of the model and the model, so no matter how you get away with it the way we operate currently you will be taking snapshot in time , abstracting that going away and looking at it , doing things to it, what's happening to this while you doing that? Is that still changing or does that freeze while you do this? And put it back in, as a client, if I am a property developer, am I necessarily interested? do I want my designer to come and present to me not me have to make decisions based upon 3D model I don't know how to open and interpret when I get there , it's the levels of interpretation in our industry unless there is an intelligent client it's very difficult for them to interpret design information anyway, I mean 3D is a step forward to that because it is easier to understand the language of a building, if you can visually enter a space rather than looking at a 2D plan , say I want to move that door from there to there if I can show it , pictures 1000 words and all that but still it's not ideal and I don't think we are at the point yet why a client can necessarily understand . My view is over as an industry or historically very very bad at communicating what we do to the people who pay our wages, we generally don't produce useful information that can be interpreted without an interpreter.
Sonia: isn't that because most of the things are getting done by AutoCAD which is the 2D drawing? As far I know design team comes up with the design and the client doesn't know what they are doing while they are working on the design, the design sort of goes back to the client, they will have a look at it, depends how good they are at architecture and understanding the design and then they will say right , we want to make these changes and the design goes back again the second stage starts. In the meantime the client can't actually come in and have a look and see what they are doing, so if you have this BIM model as a

cline you can always sort of chip in and have a look and see what they are actually doing , isn't that .....?
Quantity Surveyor: but do you want to as a client?
Sonia: Do you not want to as a client? Because obviously you are paying all the money for it, you have the ownership of the model? Why not?
Quantity Surveyor: there is 2 ways of looking at it in terms of client interaction, some clients are quite hands on and want to be heavily involved on the design process and that's its own PhD in terms of clients involvement in design process, we have been very guilty in our industry of almost viewing clients as the inconvenience to our processes, do we have to speak to them? Can we just not get on and build it and just give them the keys? With that kind of attitude, which has been prevalent in our industry for many many years it's the design team knows best go away attitude, but you will get people on both, clients in both directions someone who will be very proactiveand want to know every change, what you doing, how are you doing it, and you get others who will use words long the lines of, what do I pay you for? So, again it's the client attitude to the process that drives that rather than any imperativeform industry, in my view I think the clients should be more involved, what they should be more involved in the right decisions, which sounds really strange, clients should not be involved in Mino shay, they should be involved in making proper strategic decisions at the right point, and actually being given real decisions to make and being able to use information to make those real decisions.
Sonia: Doesn't that make it easier? Seeing something visual rather than having drawings?
Quantity Surveyor: It does make it easier in some ways, right it's very difficult if you an experienced client, a good example of this was that I worked on the building school of future program and we actually developed as a company a very simple , I don't know if you have seen the IKEA kitchen planner , we developed one of those but it was for class rooms , and you could drag all furniture in, lay the tables out, and then see as isometric, as a view how the room would look, from various look positions, and we actually got to this point doing it because what we found was we would meet with teaching staff who effectively were end users but not clients, there is an argument that end users are the client. And you would say to them that you would get a new class room in your school, oh brilliant right, what's it like, well we have allocated you 47 square meters of classroom space, 7 meters by 3, ok that's very good, that acceptance of being to visual what that looked like and how that affected them, how they could lay the room out, what they could do in that room , they didn't ask, what we discovered was a major gap between the clients understanding of space and what you would given to them, because I can draw a square on a piece of paper and say to you that's your new room , I could put a scale of 1 to 50 on it and say that represents 5 meters by 7 meters , but you couldn't then think yourself that 35 square meters, it's a word on a plan on a flat thing and it doesn't mean anything , and we also used to use photograph books , so you would show them its 35 per meters, this is what a class room 35 square per meters could look like, a photograph of a sample one .
Sonia: So you can see how big the room is?
Quantity Surveyor: you can actually think about how big it is, I think these are absolutely key client decisions, they don't necessarily understand and the 3D modelling techniques will help them to understand much better and actually to be able to make intelligent decisions about can I operate in that space? Does that fulfil my co-operate need?
Sonia: and its sort of, BIM brings all these decision makings forward? So you don't have to go to the construction site, build the room and say God that's too small
Quantity Surveyor: which happens frequently , you will be really surprised how frequently that happens , but yes, it allows you to be able to make operational decisions about the building which allows you then to be able to take steps to incorporate those operational features into the base build rather than the worst case scenarios , we used to find this again in schools a lot was that you build a school, new class rooms, they are all brand new , they all come in and say oh I need a white board on that wall , alright we have to go away run a cable back to the network, punch a hole in the wall , on and on and on, and something that costs £50 to put a data socket in when the buildings being built , costs £1000 when it has been built.

Sonia: because you have to redo it?
Quantity Surveyor: yeah
Sonia: I think that's all the question I have got, thanks for your time
Quantity Surveyor: Sure, No problem at all.
Sonia: I'm going to stop the recorder now.

Transcription – Architectural Technologist/Software Developer

Software Developer: So, the software that we wrote was called contract administrator, and it was for administering JCT contracts very traditional projects through different sizes it comes with medium and large really or simple through to complex , it didn't deal with some of the more traditional procurement routs for partnering or things like that so it's just traditional rout where you have got a client who appoints an architect and a contractor so the client contracts with the architect and contract with the contractor .

Sonia: is that the design built?

Software Developer: This is the traditional methods which I think certainly most small building would sort of use these minor work of that and some big ones would use it as well . so yeah that's what the software did , it was designed specifically to administrate these contracts , and these contracts have in place terms that there are for setting out the rules for payment and all that kind of staff, so I suppose it's like a job description for that particular project , say the contractor who paid once a months, the architect would have set the duties if there is change , there's a process to manage that change within the contract and there are time frames that communications have to be made in the contract, so that's the kind of stuff that we did.

Sonia: did you actually have to know about what sort of communications, the process in which they used to communicate, was that necessary?

Software Developer: yeah, just the formal side of it I guess yes, most email I guess, lots of it was informal isn't it? Or is sort of an enquiry , but this is about formal communications that might not necessarily been done through email, they might have been considered so formal that they wouldn't through a paper trail, certainly the time I was working there .

Sonia: so do you think they wouldn't class email as a formal communication tool?

Software Developer: well a lots of our customers didn't trust email and there was a problem as well that these and these forms or communications had to be signed and so people tended to print them out and sign them.

Sonia: why do you think they wouldn't trust emails? why don't they just use electronic signature?

Software Developer: it's a good question.

Sonia: I am just trying to understand if it's just a personal behaviour or is it company policy?

Software Developer: to be fair, there are different ways of encrypting of adding digital signatures, one of them is just adding an image and the other is to properly digitally encrypt signature so it's secure. I would imagine the lata is much the same as actually only one person can do it, the lata one, we didn't have it implemented in the software, but nobody ever really asked for it either, to be fair I don't know why people wouldn't trust it, I think it's an email is as legally binding as anything else but I don't think that people would perceive it to be that way, but its considered to be informal.

Sonia: it is interesting because people are still don't class email as a formal communication , there are some people who rather receive hard copies

Software Developer: my perception is that somebody might send a PDF file but they would send the paper copy afterwards, for records really with a signature.

Sonia: was there any other QA policy that you were told to consider when developing, implementing the software?

Software Developer: there was a work flow, so the software was based on the work flow which based around the contracts so there was , and that was implemented to some extent, so times frame and things, there were trigger events, payments you set out the frame work for payment it might be every 28 days that the payment would go out , I am having difficulty remembering actually what the process was there , each one of those events has a

process around it , so somebody would go on the site , estimate how much work was done, that estimate would go back to the office , the payment would go out , a payment certificate would go out from the architect to the client and the contractor and then the client would have to make payment within a certain amount of days of getting that certificate as well. I think it is 14 days. They get paid every 28 days and when the payment certificate is issued by the architect to the client and the contractor, the client then has to pay the contractor within the certain amount of the time so the timing of things like the issue date, and these things, were really important.
Sonia: but this was mainly for payment wasn't it?
Software Developer: that was one thing that it dealt with so , it also dealt with changes which were done through access instructions so, there is usually a trigger event for these changes as well as it might have been client gone on site and seen they don't like something. It might be that they got on site and something didn't work or they got on site and they found something and didn't realise wasn't there like a mine shaft or there is all sort of things that could trigger those changes, which mean that actually the contractor would have said that first of all this is the building that's going to be built when they are on site changed happen, so you are actually sort of amending the contract formally with these instructions that instruct a change. Does that make sense?
Sonia: yeah, so these changes would only happen on site?
Software Developer: well this yeah, this is after, the process that has happened is the architects designed the building, the clients appointed the architect, the architects designed the building and pointed the contractor and that contractor was appointed on a design , you know a completed design that as all the drawing and specifications done for it. Then when they actually come to build it all sorts of things could happen that mean that there is no longer designing exactly what he quoted on , so if there a cost implication to those changes after he is signed the dotted the lines that he is going to built this house , then this has to be processed to take care of that, he thought he were going to get a house for £120.000 but because you have changed to marble its now going to be £130.000 , so to agree with that change it has to be a process in place and that's all detailed in the contract it says ok if you know only these people can authorise these changes and they have to be agreed, and the cost has to be agreed this way .
Sonia: do you know anything about the details in terms of communication, for instance was there any policy about the amount of time or how quickly they had to reply to an email or an enquiry or an information request?
Software Developer: No, not from that point of view, only the turnaround for these things, they are quite quick, so if something gets issued by the architect and the clients got to respond to that or if something is gone to the contractors there are deadlines for them to respond, they usually sort of in the region of 2 weeks which is quite tight really if you think somebody might be on site and not in the office, and to deal with that traditionally through papers is quite difficult
Sonia: so you don't know anything about email policies? Most of the questions I got are related to communications, as you said you should be working within the company to know all these processes and policies, but what you explained about , the clients and the architects working together and how they used to print everything out, it's quite interesting,
Software Developer: Sometimes you wonder thought weather it's the constraints of the software that does that as well, so this software is producing these documents which is really easy, but there are whole systems where only so an architect, constructional and repayments ,there will be only one person in the office that is authorised to sign those because there is a big implication with them, and that person might not be the one that's got the license for the software so it might actually be the secretary in the office that types up these architects instructions so she is the one that using the software because the architect scribble some stuff, type that up for me , so she uses the software to generate the form , and he has to sign it or she has to sign it, or somebody maybe in a different room that has, if all they have to do is sign they are not going to buy a license for the software.
Sonia: so it could be the cost constraints.

Software Developer: or the constraint of the software, actually the only way to deal with it is the secretary prints it off, and the partner signs it. All I know is what customers have asked us, I don't really don't know what happens in practice but I know that a large amount of people that were producing these official communications were admin staff.
Sonia: who would, in terms of decision making, if it's an admin obviously dealing with these kind of stuff, who would do the decision making?
Software Developer: well I guess there is a chain , somebody's detailed what should go on or in fact there a process in place that says a payment of these is made every make sure that this goes out.
Sonia: so the admin would be in charge of the information flow, what if or she make a mistake?
Software Developer: I think that's where the signature comes in from the partner, maybe worth pulling up one of the forms but for I understand what was happening was, in most of the practices somebody was either scribbling or going in and saying : can you issue an instruction that says this on and the admin person would deal with that and it would get printed out and send for a signature on it.
Sonia: what if she sends it to the wrong person to sign it?
Software Developer: I think, I don't know.
Sonia: it's just interesting, we are all human beings and everyone makes mistakes, I was just furious what would happen if somebody makes that mistake, if they sent the wrong information out or if they send information to the wrong person what would happen then?
Software Developer what procedures are in place for that to stop happening? I don't know , these forms the forms themselves that are generated were not legal forms, and they were not legally required to be forms, but the design of them has kind of become standard in the industry and on them they have all of those details so it will say who the contractor is, who the client is , and a list of who it needs to be sent to and actually in the software there was a mechanism for managing that so there was the concept of the distribution list , so you would setup a project team in the software and there was a, like a master distribution list that said if you are sending out and architect instructions , one copy goes to the contractor and one copy goes to the architect and all that got printed out on the form so there were mechanisms in there to tell you who should be really receiving the copies, and that would be all printed out on the forms and the addresses that needed to go to.
Sonia: ok. Well Thank you. I'm going to stop the recorder now.

Transcription – BuraHappold – Building Services Engineer

Sonia: I've started the recorder now. Could you tell us a little a bit about what you used to do in industry?
Design Engineer: Right, my role in industry, a bit a history is I joined a multi-disciplinary called BuraHappold, working out in Bath in England. My role was as a design engineer on the acoustic side of the construction but bringing with it my background in building services engineering which meant that I had to lead the design of acoustics whilst integrating the other inputs that come from a company like BuraHappold so seeing how that all affects the structural design, how it would affect building services, engineering design both electrical and mechanical with other issues that affect the architectural design of the building which has great affect on that acoustic side including environmental side of it as well.
Sonia: Obviously you used to deal with information, drawings, documents and specs? Was that done through email or extranets?
Design Engineer: It all depended on the project and how the project was to be communicated. Some projects were very low key so some projects were case of old school so mix of design meetings, face-face meetings, telephone calls, emails, etc. Which creates the old fashioned of doing things which we have done for 100 years? A number of projects started the central hub approach for communication, I can't remember all the daft names but the main one was Buzz Saw for Autodesk which was like a social network for a project. So, face book actually existed at the time but that's what it I was. You set up who you are, what you did, you had an email hub, you had document share area in there which was set up by a

project lead usually the project managers who would do that. Often they link the cost control people, turner and towns end type of people that would set these up and then people have rights to certain areas. Drawings, emails and minutes of meetings would be assigned to certain areas. There was a variation on complexity of the different types of products we saw. Certain companies have their own cost parsons and they could be tweaked by various companies to suit the project but they were effectively a social network for as I would see today the wall in face book, that's what you get on these things, it is an area where you can upload documents that can be seen with others and rights can be assigned. I can upload something and say no one can change it. They can add comments to it. And someone else could upload stuff that could be changed. There was a revision automatically generated.
Sonia: So there was version control in place?
Design Engineer: Yeah.
Sonia: Was all the functionalities getting used properly?
Design Engineer: The issue with anything like this as everything is engagement with all of the design team. So also there were some contractual issues you kept seeing coming in. About who was allowed to change what? Who changed what? Then did the program then tells someone that has been changed. Some people would embrace it and put all their information on. It would be fantastic for them. Other people as you see in academic as well don't use it even though we are all supposed to. It was getting the engagement. One of the ways of solving is the case of that some of the projects that are set up the only communication allowed is through these extranets. If you don't communicate through that other emails would be ignored or deleted. You have to communicate through the design team through this process. It did mean it does create issues for communication because it means that when an engineer or a designer who logs on in the morning, they log on in to their normal systems; they have other projects to look at. They have to specifically make the effort to log on to that project's website to see that there is a new email for them if that website is not telling them. So there could be a break if you didn't log on for 2 or 3 days, if an important issue come up you wouldn't know it.
Sonia: Right, that raises 2 questions. One is, you didn't use to get any notifications through email?
Design Engineer: Again, some of the sites would do it automatically, say there is an update. But you would find is that because of the vastness of the information that is added to it, you get lots of updates and that was a temptation to go and turn it off. Some of the better ones would say when you upload a piece of information you could tick a box to say this is of interest to this person, this person, this person, and it would only inform those people that there is an update to it. Some just didn't tell anyone anything. It was just a repository. They had to go in and either look for it or set their preferences to be told that this has been added which of course if they are not IT experts which we have a massive people going through industry who aren't, not to that level anyway and not happy with it, they just never engage with it. They never get the information, sometime it didn't work. You end up with people saying can you send it to me through the post. It is breaking he chain.
Sonia: who would choose these extranet sites? Was it client's choice?
Design Engineer: It would be the client, sometime it would be the client, particularly if it was an educated client. A lot of people build buildings once but clients that build a lot of building so you are looking at clients building schools, they would know and they would sometimes demand it. I think most of the times I used it was actually coming from the lead on the project and because of the procurement process of buildings in Britain over the last a few years, there has been something called PFI and therefore to do PFI's, do you know what a PFI is?
Sonia: I've heard about it but not 100% sure.
Design Engineer: I always get this wrong, Private Finance Initiative. Just to clarify what a PFI is. If I, as a person want a building, I could put a brief out to what I want as a building it needs to be this and this, performance, specification. I then ask for bids under PFI's. What I want is that someone would come along, I want to talk to one person and they will offer to build the building for me and run it for the next 25 years. That person would have created a separate small company called a joint venture. And that person therefore would have

gathered all the people who they need to build, design and run the building. So they would have come up together and they would have brought in engineers, architects, cost control, facility managers, and security consultants together. But I as a client I wouldn't deal with 20 people, I would deal with the joint venture. And the person that runs that venture because they have to put the money in to bid which is expensive they usually set the sense up how the communicate of the design team is going to work. So the heads of the joint venture would make the decision which was often in the last a few years, the builder, and the main contractor. By far it used to be the client or the architect but in my personal experience it has been much more led in Britain by the main contractors because of the PFI procurement root and I think there is a close tie between how projects communicate and how they work to how they are procured. Because the procurement root sets where the decision making power lie and therefore how the roots of communication speaks to it.
Sonia: Do you think you used to deal with too many emails a day?
Design Engineer: I have reached, one of my happiest days in the recent past was, let me think now, October the 20th 2007, that is right because that is the day I handed back my Blackberry. I was over the moon; I think blackberries are called crack berries for a reason. I used to handle a minimum of 150 emails a days. All of them would be demanding some input, some thought and the issue that then creates from a design perspective is, it doesn't give any time to consider. You need consideration time. You can't make decisions that could actually cost in the long run could be millions of ponds. And even though someone knows that they still send an email and expect an answer within the next 5 minutes and they seem quite happy with that. They spend more time buying a pair of shoes than they would when they send you an email, should we build walls like this? So I think there is death by email and the control of questions and I would always wish and some of them did say there is a response time, an expected response time. Very rare this, most people thought well I've sent the email, therefore I've done my job therefore I expect a response in 5 minutes. Some other people use email system as a get out of jail, because if I can send an email that says yes or no I've done it. So the email was when I was last in business out of control.
Sonia: I was going to ask you about the specific time that you had to reply.
Design Engineer: The communication websites, it used to flag up you have a new email and it used to then go different colours when you left it longer, you haven't either read it or responded to it and it would start to flash urgent.
Sonia: so do you think that is a communication problem or a collaboration problem? (Explanation about communication models)
Design Engineer: I think it is the culture. It is the culture of the construction industry. Sadly, there is not so much in Britain, although it exists in other countries you go to a meeting where each person goes to it bring a lawyer with them. Everyone is looking out to protect their interests within the project. So as an engineer when I do a design I am responsible, actually strictly speaking I'm not only responsible for the design, I'm responsible on a personal level, I could be personally sued for the next 20 years for that design so therefore I have to insure what I say hopefully is right based on the information I receive. That sets up a quite undertone of litigation and therefore people are using emails and using communication processes to head problems off in the past. I remember saying to you, I sent an email to you about 5 years ago, you can't come back to me and change it now. That sort of mentality. And I think that culture that exists of; I know I asked for that and you didn't do it, is a construction culture. Because although we work as a team to build a building we are a team with very individual desires. It is effectively like watching an episode of the apprentice. Where in team they are trying to work for the same goal but they are all individuals trying to win. And unfortunately the projects which work best are where you come together as a team and work as a group of friends and not as a group where they are trying to be litigate to each other and the communication that therefore generates needs to be very careful and controlled. How you handle that communicate and getting communication, don't just send emails, don't just send revised drawings. I had one project where there was an architect and it was a care home in the north east of England, lots of houses and flats in different styles. And when they changed one door in one flat, they would re-issue every drawing both electronically and sadly via post. Hundreds of drawings, masses

of mega bytes of information coming out, you go through them all, thinking what has changed? Oh, a door moved 400 millimetres. They were doing it to protect themselves. But they were flooding it because actually then has a duty care, I got new drawings to look at and I have to say I've looked at them and if I haven't eventually down the line I could be exposed. I have to then spend an awful lot of time doing it. The ease of communication, especially electronically has allowed them to do that. So every new technology generates its own evils and good stuff, don't get me wrong, I'm very supportive of it, I think we need to move away from that but I don't know how. So you are right. It is never the tools, we should never blame the tools, and it is just a communications, nice and easy and quick. But we still controls over t.

Sonia: Going back to what you said, somebody might come back to you and say I sent you an email about 5 years ago; is there any formal support for archival?

Design Engineer: Most companies will have an audit trail. I speak from my company, they had to have an audit trail, and everything was kept. That is starting from a very low level stuff, your hand written notebooks that you take to meetings and scratch a little note to go back and remind you, they were all dated and logged and kept with the project. You had to be very careful what you wrote in the notebook because one day it could appear in court. The same goes through every level of information. All email should be archived off; all drawings should be archived off. Electronic copies were eventually at some point, dumped down on to a tape system. They taped grandfather, father, son copes of all that. It kept them offsite and logged on site in to a special archive. And all emails on every project were kept. And they were kept, you might need to check on this, if I remember correctly BuraHappold kept them for 4,5 years, but theoretically we should keep them for 20 years. We were certainly keeping stuff for 5 years and there was a whole process where you could get stuff out and occasionally we were called on to gets the dates in. Most of the time there were issues of being taken to court for bad designs. But who is going to pay the bill for this and how did the situation come about that this failed? Because people had to get the stories straight. I can give examples of a museum building in Britain where a small mistake by an outside third party where that third party didn't look at a drawing and got the levels wrong for the stairs in the space which meant that none of the ramps, none of the stairs worked for disability across the whole museum. And the variation order to do it once people realised at the end of the project was over 2 million pounds. It was one person who was a third party input, didn't look at one drawing and it went to court and every bit of data had to come out to look up where the break in communication was. The other side of that is health and safety which controls a big thing in industry. I know it has happened again on a project for BuraHappold recently, it is in court now and it happened a few years ago as well where there is a death on site. If a death occurs on site, all of the design team under regulation is responsible for the safety of not only the design but the safety of the operation of the building; you have to design for safety under construction safety management. (Explain about health and safety). When you have got disjointed emails and notebooks that becomes a little bit of a pickle, it becomes a finger pointing exercise. Where you have projects which are central hub and there is a link and tie and hierarchy and dated and audit trailed actually becomes a lot easier to say well yeah we said that, we mentioned that. Because unfortunately it does become a case of did we consider it or didn't we? So actually the issues raises with communication become more important during that. So yeah, we do have to keep the stuff and the ISO ratings that companies like BuraHappol have, when we get Lloyds coming in, they would ask us how you audit your emails. And we would be checked on it.

Sonia: interesting. What about distribution list? How does that work?

Design Engineer: Distribution list? Yeah, that was a tricky one. In terms of who wants information and when, when you produced it, it was always a case of I think it is socket in sea approach because what generally happens is, you produce some information and you send it to everyone you think you should send it to. That is terrible to say but that is the honest truth. Sometimes you would get, if it was an old fashioned communication approach by just email, reports and letters, you would send it through. You would make the phone call and you would probably call the project manager if there is one on the project and say

who needs to see this report and see what they would say. Some people just send it to everyone. If it is a centralised hub approach, like Buzz Saw, you can just upload it and make it visible to all, or visible to some, you generally as you go through the project you would find that who would wants this information?
Sonia: So you do that for every bit of information? Report?
Design Engineer: What you'll find is most people will say who would want input to this? Who would want to see this information? What people are worried about is that you don't send the information to the one person who needs to put a little bit of input to it. I think the attitude would be if I send it to someone and they are not just interested that is their issue, if I've sent it which in a course the reverse of that means I used to get stuff through which I would be; why have I got that? You eventually say, I know why they are doing it, they are doing it for the same reason I send my reports to everyone. Some projects will be better handled and better managed where there would be a known distribution list of who to do it. And some of the shared sites what you get is like interest groups, and they would, you would sing up to the interest groups that you are interested at, like acoustic report so all the acoustic reports come together. Someone like landscape gardeners might not sign up to the acoustic section. It is always a danger that because you never know what is going to happen. You still find people sign up to everything anyway because they want to know what is going on. Distribution lists are tricky because you have to keep a very close eye on everything that is going on. What I would say depends on where you are on in the design process, if you are a project manager or a cost control guy you are going to be in everything, should be in everything. If you are the structural engineer, you should probably have an interest in everything. If you are a design manager on the services side you will be in everything because you want to know what is going on. If you are at a technician level which might still be going to meetings and discussing details but you might not want, you think it is my design manager responsibility. So actually you get slightly variation, although the same company, same group, different distribution lists for people internally and where they are. I think that is quietly badly managed. I think everyone just signs up to everything.
Sonia: and did you get all of these via email? Or did you have to print them out and send them in hard copies?
Design Engineer: yes, where possible we would try and keep things electronically because there is a requirement for carbon saving argument of not sending stuff in the post. Also you can get receipts for it and you know they have got it. There were some issues with email during my time in BuraHappold, actually whilst I was there when I started and email was not contractual and about a year and half after I had started, email became a contractual document. Because there were enough court cases that say that an email has been written even though it has not been signed or anything. So if you wrote casual email, it is still valid. But some people still insisted letters. When you doing early parts of the projects where you are setting your scope and agreeing your scope and fee, there are still a lot of things that has to be done on paper with a signature.
Sonia: Is that because they want to keep it formal? And they don't class email as a formal communication?
Design Engineer: Yes, exactly. Some of the major projects which had to be signed, depending on the value o the project and the value of the insurance that you had to put to it, PI insurance going in to it, you had to then count the signatures by various degrees of people in the company, you might need a chair man and you might need official seal and that has to be done, the only way that can be done is a paper. That then carries on forward in to the project whereby you get some people are quite happy to accept electronic drawings and live with it and they can communicate with it and they can do everything. It is an editable drawing, it could be a PDF of an electronic drawing, that is fine but some still will say we want one set of hard copies of revisions of drawings. I still think we are in a situation where there are a lot of people who head up to the senior people who make these decisions in industries are, I don't mean to be ageist, but a lot of them are of the 50+ category and therefore for them now to change the whole paradigm of how they are working in industry, right we will go only for electronic versions only for all of this, some of them find it very difficult to do. Therefore some of them still want hard copies with engineer's

check signature on it. When we write any report, it would be published via email or buzz saw, we would still send a hard copy and a front page would always have the signature of the authoring engineer, a signature of checking engineer and possibly a signature of a senior design manager. Therefore that is what we say at this point in time a document. I still think that generates a sense of security to some people whereas electronic ones still feel vague even though it is exactly the same document.

Sonia: So, it could be a personal behaviour as well?

Design Engineer: Yeah.

Sonia: Going back to, you said sometimes you have discussions, meetings and telephone discussions and things like this; would you still have to send an email out for confirmation?

Design Engineer: every time we had big formal meetings, there would be of course minutes of it but if you had a design review meeting so you are sitting round a table with the architects and structural engineers and you are putting ideas on a piece of paper. If there were, I remember sitting in brilliant design team meetings, absolute great fun, where you have sheets of A3 and people are discussing specific parts of buildings and how to tackle them from each of our independent disciplinary approaches and you sit down and you have affectively a controlled argument with professional people coming together. I remember at the end of those, the A3s would be gathered, people would sign them, date them, put numbers on them, they would be PDF and sent out by email. We are not saying the answer; we are saying it is our starter for 10 for this point. Other meetings where you might just have with the architects to run through things. At the end of it, I know within a day or two the architect would send an email to say this is what we have understood from the meeting and I would send an email to say just to confirm what I have told you. I would never just leave it as a meeting and hope on hope they remember what I said. I would always write it back for them. Depending on where you are in the construction team, from my particular perspective as an acoustician, I worked on about 150 projects. At one time I can remember 68 live and running in either early days design team meetings getting through to hand over, 68 running. I challenge anyone to remember all of the details all the time and what they said, especially when I have got a care home in the north east and block of housing, a prison and a student hall somewhere else. The facts of each of those can start to mix up in your head. You cannot keep it all. Therefore you are writing the email to someone else not actually for their benefit, you are writing it for your benefit. To remember I said that to that person on this date. You are quizzed on it sometimes; people come back to you and say when did you say this when? When did you do it? And you go back to emails. (Explaining about keeping all emails and projects)

Sonia: if somebody left the company, especially if they had an important role within the company, what would happen then? If they were off sick?

Design Engineer: This is where by, the company shouldn't have locally stored only information, so ideally you should have your outlook set up so it is on an exchange server and you are logging on and it is downloading to you. But the main copies remain on the exchange server, you should not have outside sources of communication there and one of the issues with buzz saw and these central hub ones is the ownership of data. That was a big contractual issue. Because whose server is it on? Who has access to that server? When the project finishes who maintains that server? Who gets a copy of the data? There robustness of data becomes an issue because whilst it is your email and your exchange server and we have backups of it, it is great. If it is a project manager who has it, how do we know they are going to keep it? How do we know that for the next 20 years they are going to keep it? And so you can at the end of projects have complete download and distribution of the whole database. But also therefore what you'll find is people that are having using buzz saw types, going through downloading all the stuff whether they need it or not and keep a mirror copy of it and that is so defeats the object of it because you want one multiple set of data. You don't want to think is it that one or the other one I should look at? Again it is that worry about but you should never ever have someone who has local copies of email and stuff like that on laptops which then they walk out the door with and IT take the laptop back and delete it and give it to someone else and realises it is project data. They were not allowed to do it. So all the project directories that we had were all on main server and when you logged

in to the company all it did is copy and synch all your project data on your laptop so if I changed anything on my laptop and logged in it then synched back to the main server. So I didn't have any stand alone data at all.
Sonia: Did everyone have authority to send emails?
Design Engineer: Good question, very good question. Everyone had the ability to send emails. But whether the emails should have been acted upon or not was very closely protected. So I have to say BuraHappold were a bit neolithic in their approach to some things because one of the things was BuraHappold would only give business cards to associates and above. And that was a problem actually, I found it a problem, I joined as senior engineer which meant I didn't get a business card. And then a year later I changed which the policy takes that long they wouldn't do it immediately. But a lot of the staff that I had, so I had some recent graduates who were coming in and one of the issues I had with my particular field was we had to have a lot of meetings with a lot of clients, some of them international and they all expect business cards so we had to have business cards. But BuraHappold had this mentality that you could only make actable decisions if you are at a certain level and they link it to their business cards and to their emails as well because they were saying; you can't email someone and tell them to do something. That email has to be signed off or go through somebody else. With the level of data and the level of communication started to be produced by modern buildings and also the requirements of PFI and all of that, the ability to ask question quickly. There were a lot of people generating a lot of question which would flood design managers. You start getting question coming through and I don't think I ever saw anything that really that clarified. You are right; there is something that should be in place that says, this person can make a decision and this person cant. I never saw that in place, it was quietly in place at the background but not formally.
Sonia: Some companies have a role for information flow and directing information to the right person.
Design Engineer: That certainly was not my experience and I didn't pick it up. I had it where, I had project managers in particular insisted all emails were copied to them, they wanted to see everything. The problem is the vast number of emails; the level of communication on a major building project is just huge. And the size of the data files that go through as well. I think, I would hate to be that person to be the data flow manager on a project. I think it would be very difficult to handle everything. I think eventually it will fail, I really do. The amount of emails they must get. On a major project you can have an architect, at some point cost control manager, landscape architect, interior architect, acoustic, civil engineer, main contractor, sub contractors for building services and electrical and everything from furniture to security, client's agents. You can go to design team meetings where there are easy 60 people. Badly managed design team meetings by the way, all of those 60+ people would have a comment on it, the amount of information flood through that person does need controlling but the amount of information is vast. And I think if a human is in charge of that is going to fail, it will fail. It needs to be more automated.
Sonia: I think one the reasons for having a role for information flow is that some people might send the wrong information out or send the information to the wrong person. At least this person is his/her job to ensure the right person gets it.
Design Engineer: yes, I think what you are saying is, although we all work in one work, construction, we have very specific specialities, not one person could say that is the right information. What they can say is who needs this information? And that decision could be made but I don't think anyone can make comment on the information because you need someone who would, it is too much, you know. It is up to senior design team who needs what and when. It is very a brave decision to say this person not needs this information.
Sonia: you mentioned copying people in, you have done it yourself? Do you just copy/blind copy people in?
Design Engineer: I hate that. I have to say I desperately try not to, I would like to say hand on heart no I've never done that because I would consider myself as IT aware but it does annoy me when information has gone out to the design team and someone thinks that they are being helpful by resending it to the design team because they haven't read who it has

gone to. I'm sure by mistake I've done reply to all rather than reply but I think that is an issue, I have used blind copy because no matter how much I would like to think we are all friends. Sometimes you have to ask an awkward question and get an answer and I have used blind copy to someone and say, specially where you can feel the relationship is souring and no matter what I'm saying the I'm getting responses that seems to ignore what I'm saying. Perhaps a partner has been involved and I have blind copied to the partner to show I am telling them but they are ignoring it. I don't think we will ever alter that. What I would say is, if we have an open communication system, where all the information is there and viewable by everyone, that means we would be a bit more careful about what we say because we know all the information is there.
Sonia: I was just getting at that point about conversation threading. If there was an issue raised how would you inform others and ensure it is solved?
Design Engineer: Tricky one, I think as the 2 models of the standard communication, i.e. email and letter or the central hub version of it. In the standard communication one it is very difficult because if someone has asked a question and they have just sent it to me because it is a direct question of my speciality, I would hope I have answered it and you end up in a situation where because of the huge number of emails sometimes you miss one and they end up electronically prodding you to say I sent you an email what was your answer on this? That comes down on to different parties answering each other's questions. There is no check on that; there is no enforcement of that or overview of it. Whereas when you get the central hub version of it when someone sends you an email with a question they would put a response flag on it and they would say response is expected in 2, 3 days or a week, whatever. And after 5 days or 2 days it would say tick, and once you have responded with an answer it clicks off. They can always come back and say you never answered it and click it back it on, so in the slatter one I gave there is a check that there is a response and there is a communication going on but there is no check to say the issue has been solved. That is a technical aspect and I don't think we will ever get to unless you start involving third parties but the formal one I mentioned is that is just professional relationships. There is very little way of doing that other than; I don't know how to do it. it would be very difficult to do it. As we get more central areas which is the BIM approach to it, I think that will start to say has this been solved? Because you can put a freeze on drawings until someone answers this question no one can alter the drawing that would then create a great pressure on someone to get an answer. That would be a good thing.
Sonia: my last question, was there a policy or any guidelines in terms of, did you have to deal with one issue per email? Or could you mention a few different issues in one email at one go?
Design Engineer: Yeah you could, I think in the general email communications you could answer as many question as they had asked in an email. If you came back from a meeting and you had a list from your notebook of all the things you could put them all in an email or attach a document to answer the questions. I never came across it; there was no criteria to say you should only deal one issue per email. When you had the central hub areas again people would have threads in them and there would be discussion forums and that sometimes isolated certain areas but because of the interrelationship and decisions in construction you find they go off theme very quickly, it is difficult to keep it on track. You have to answer a lot of things at the same time.
Sonia: Well, that is all the questions I have. Thanks for your time. I'm going to stop the recorder now.
Design Engineer: thanks you and no problem.

Transcription – Ryder – Design Manager
Sonia: Paula, I've started the recorder. Could you tell us a little a bit what you used to do?
Design Manager: I was a design manager in industry, so I did my degree in design management and graduated in 2003 and I worked as a design manager for contractors. So based on site and then I worked for Ryder Architects as a design manager on city library in town. So that was the last project I worked on before I started in university.

Sonia: obviously you used to deal with information and drawings, did you have extranets for different projects or did you use email as a main communication tool?
Design Manager: Most of the projects I worked on had extranets and because I mainly worked on PFI projects which are just essentially a form of Design and Build, the extranets were set up by the contractors so we were responsible for running them, so I had experience using a few different extranets; Information Warehouse, BIW that we used on library which to be fair was the best one that I have used. But you end up sending information through emails, you know the stuff that are kind of draft or informal and then sort of officially issue things using the extranets if you like.
Sonia: How did you use, well obviously if you are sending emails there is no version control, how would you??
Design Manager: No, it would just be a case of; here is a sketch this is a sort of a thing we are thinking about, is this what you mean? Yes, and then if it was just go ahead and issue that with a sketch number on it and put it on the extranet. So before sort of officially issuing it just to run it pass people. I mean the extranets were used for drawings, specs and even minutes of meetings, stuff like that. It was really good and everyone did use it because particularly on the city library it was well managed. So you knew that if you went on there it was the latest bit of information you were going to get, the latest drawing. I think with a lot of the extranets I have worked on they have been badly managed, people are publishing information to it but you can't help which is the latest reversion, or when things have been done, you can't track back through things. You have to be careful about managing it properly.
Sonia: Who was managing the site?
Design Manager: ??were managing it, it just happened that the person that had running it was really organised person. He was not a design manager but he was effectively doing a design management role in terms of looking after documentation.
Sonia: Did you use to get any notifications or alerts via email? When thing used to get changes?
Design Manager: Yeah, it was set up so that you get automatically notified for whatever was relevant to your particular bit of work, with us because we were the architects and had to know everything, so then we downloaded, we comment on it using our own internal QA system so we had form that we used to fill in and then we would scan it and send it back to the ... for distribution.
Sonia: right, ok. So do you think you used to deal with too many emails?
Design Manager: Oh, stacks too many. At one point we were up to 150 a day, it was horrible, it was absolutely ridiculous. You go away for a couple of days for business and you come back and it is ridiculous.
Sonia: I can imagine. So these notification you can easily ignore them. Did you use to open every single notification to see what it is? Or did you use to just ignore them? Because I know some people block/ignore or delete them!
Design Manager: I would open it up, see what it was then we used to get the admin staff to download the information or get one of the junior architecture technologists to do it for us. So they would download whatever it was for our records. We couldn't ignore it; you would know the one thing that you ignore turns out to be very important information that is essential to have. You have to take notice of them. More of the problem is people sending irrelevant crap. You know, I think it is just like the amount you get causes you to sort of to start not taking notice of things.
Sonia: Was there any formal support or any policy for archiving?
Design Manager: Yes, everything had to be archived paper copy.
Sonia: Paper copy?
Design Manager: Yes, they were still doing paper copies because there was a changeover. They decided that they were going to start file everything electronically but they were going to do 1 or 2 years overlap in terms of paper copies but they were spending so much on archival that they needed to make a change. There was something like an insurance that RIBA document which said that you had to do it in paper copy. I'm not sure but there might be something like in a guidance document by the RIBA or something that said at the time

we still had to keep a paper copy or something like that. But yeah we were still keeping paper copies.
Sonia: did you have intranets as well?
Design Manager: Yeah we did, yeah.
Sonia: Did you have a centralized server?
Design Manager: Yeah, it was called Ryder net.
Sonia: So you would still save a copy of all drawings and information on a server as well as keeping a hard copy of it.
Design Manager: Yeah.
Sonia: Ok, that is interesting.
Design Manager: Really time consuming, that's for sure.
Sonia: Was there a person in charge looking after this? For archival or was it up to individuals?
Design Manager: Every team had an admin person who was responsible for filing everything, you would give it to them and they would file it. So whether you could retrieve it or not was directly related to confidence you had in your admin person so if they were good it was great you could always find everything. If they were crap and filed things at the wrong place you were stuck. You probably retrieve them electronically anyway, I certainly would.
Sonia: What about your distribution list?
Design Manager: For everything that were issued, we basically had an excel document which listed all the drawings and specification and then we had a distribution list at the bottom and you would just tick who would get what depending on what it was and then send it out electronically to them.
Sonia: Again it would be the admin's job to send it out?
Design Manager: It would depend on the confidence you had, because with some of the admin you would try to get them do work for you but it would end up them sending it to the wrong person or you know it wasn't done accurately. So a lot of it probably we do it ourselves. At the end of the day it is just sort of sending out via email
Sonia: I was just going to say, what if the information gets sent to the wrong person or the wrong information goes out? Is there any policy for that? What would happen then?
Design Manager: that would probably be the case of me having to send emails around to everyone; sorry we've sent the wrong thing or whatever. I think you just rely on people's professional expertise. But there are always cases where things can go wrong. And people don't get the information they need.
Sonia: What if it has huge implications? If it has cost you time? Cost you money?
Design Manager: That's just kind of have to lump it really. At that stage all you can do is try not to make the situation worse.
Sonia: And, did you used to use emails, what software were you using? Was it outlook?
Design Manager: Yeah it was outlook?
Sonia: Did you use it in a structured way? (giving examples)
Design Manager: Yeah, but I don't find the flags very useful. I would just to leave them in my inbox I auctioned it. I used the inbox as an action list and file everything else.
Sonia: So you weren't really using it in a proper way? Follow up and things?
Design Manager: I have tried it but I don't find it very affective. I don't know why.
Sonia: Some people use the Inbox, especially Outlook, as a task management, archival and information management as well as an Inbox.
Design Manager: I've tried the task bar on the side as well where you can put your tasks that you have to do but that doesn't seem to work for me either.
Sonia: Sometimes you get people with other people who are copied in. When you reply, do you reply to all? Or just reply to that specific person who has sent you the email? Do you pay attention to this kind of stuff? Or just blind copy people in?
Design Manager: Oh, yeah. It is really important. It depends on what it is. But it is very very important. I would always look at that. Because obviously, specially if you are in a situation where I don't know something gets sent out say for instance; the wrong piece of information gets out and the clients is copied in, the last thing is to reply to all. They see that there is an

error you want to tell the person who has sent this, you know you have done this? You give them the chance to sort of put it right. But I think some people are really bad doing that. I think lots of people just reply to all.

Sonia: was everyone allowed to send emails? Everyone had authority to send emails?

Design Manager: Well I've got quite a funny story. We had this student who was working with us. I think he was doing his A levels and working over Easter. He was one of the managing director's friend's sons or something like that. So he turned up and they gave him an email because he was going to be there for a few week. He sent an email to a developer, basically he was being supervised by this guy and he was mouthing off about something; oh this is all wrong, why they got a London architect working on this important Newcastle project? This kid basically wrote down all of his supervisors opinions, as if they could come off his mouth and sent it from a Ryder email address to this developer and the developer clearly saw it and went oh yeah from a Ryder email address and sent it back and there was hell on that he had the email and sent it through. After that they stopped people who worked for a short amount of time having an email address. You don't want junior members of staff sending emails that are inappropriate to people. I don't just mean the wrong information. I just mean sometime they don't know how to write an email, they don't appreciate what it looks like or the tone. So I think it is a skill they have to learn, they way of doing that is to say to them before you send it out I want to see what you have written so I can make amendments to it to make sure it is appropriate. But that is time consuming so people don't do it. Or they get an annual person to send it for them. So I think it is supervision really, isn't?

Sonia: Was there anyone in charge of information flow? Was there a role for it? Or again admin's job to do it?

Design Manager: In terms of, on the project you mean?

Sonia: Yeah, you know how you have your distribution list? You need to send the same information to everyone and sometime it is different information? And sometimes receiving information from externals and directing it to the right person? Was there a role for that?

Design Manager: No, I think as the project leader, I would set up the distribution so I knew that for certain packages we had to include certain subcontractors because you don't want the partition guy getting all the lighting information. You have to work that out on the basis of you know they are probably going to need that. And then also we had a list, so at the start we do a cartoon set of all our deliverables so we know every single drawing we had to do. We virtually know what size it was going to be, what scale it was going to be and we would know when we were going to send it so we come up with a plan for when to send it.

Sonia: For every project?

Design Manager: That is specific project that was the standard in the office that we were supposed to but I know that they didn't do that for every project.

Sonia: So it depends on the size and cost of the project?

Design Manager: Yeah, it would depend on the organisation project leader to be honest. I mean there was a company policy without a cartoon set you wouldn't get your resources allocated to your projects, but there were plenty projects that I knew about it and they didn't manage or organise themselves efficiently. Nobody would be in control of it.

Sonia: So what was the culture like? Was everyone happy to use different technologies?

Design Manager: In terms of working in Ryder, everyone was working on different extranets, because the contractors usually select the extranets. So for instance, the team we were working on Lain ... projects they would be working with their particular extranets, kerelian would use another one. So the admin staffs that were uploading had to get used to being able to upload the information on different sites and how they all worked.

Sonia: What about the people on site? Apparently they are the guys who don't like using technology?

Design Manager: They guys in the office were fine but to be fair, I mean we are not at the point where you can go out and build using a laptop. So it is always going to be paper based, as soon as you get out of the site cabinets on to the site you are going to be down to a piece of paper.

Sonia: What about these new pads? Some companies are using something like iPad.

Design Manager: I would like to see that. I really would. From what I have read about them, the capabilities of them it is to do with the amount of memories they got and running it over a wireless network. If you are using a model it is difficult to be able to run a model on them. Eventually that is where we have to go. It is stupid that you are doing a 3D model these days and take a bit of paper out with you on site, specially site managers, they have a habit of getting a drawing at the start of project and mark that up and colour it in and they will never get another drawing. You walk in the cabinet still the same drawing is still on there. That is just the where things are I suppose.
Sonia: If you have any discussions over the phone, or even face-face, do you still have to send an email afterwards to confirm it? Like a confirmation email?
Design Manager: I would if it was important. Yeah definitely. There is too many times when you have a conversation with people and you agree something and then it goes wrong and they'll deny it. I've been caught out with that so many times, so I always would but again it is something you have to learn to be disciplined about.
Sonia: If somebody left, someone important what happens then? What about the drawings and information they have saved on their PC? What about their role in terms of information management?
Design Manager: I suppose the impact is less if you have an extranet.
Sonia: Even if this admin person you said, they are in charge of archiving...
Design Manager: Yeah, I mean it would depend on, if we got someone else to replace them they wouldn't be able to do it straight away because they have to get up to speed with all the systems so you probably end up doing it yourself. In terms of stuff being, architects are really bad at this. They love saving things on their desktops, the drawings they are working on they save it on their desktop and if they are off ill or something you can't have access to it because you haven't got their passwords. I don't know why this, it is like there are just some characters who they have to be completely in control and secretive about what they are doing and until whatever they are working on, whether it is a drawing, until it is perfect they won't let anyone see it. But to the point where they'll just hang on to it and not issue it until it is really late. It is always tend to be people who save things on their desktop or C drive and you don't know where it is or what is happening with it.
Sonia: Do you think it goes back to the organisational culture? People not wanting to share their drawings and information with others?
Design Manager: Yeah, I guess it is a personality thing.
Sonia: It could be a personal behaviour.
Design Manager: Yeah, especially architects, they are nightmare at it.
Sonia: Is there no specific policy or guidelines that you should follow?
Design Manager: oh yeah, you shouldn't do it.
Sonia: They don't actually stick to it?
Design Manager: No.
Sonia: Right, if there is an issue raised, how do people track it to ensure it is solved? In terms of conversational threading?
Design Manager: I would say, the main problem would probably come through meetings that you would have in a project. So probably the best representation by current ongoing issues would be the minutes of the meetings and when they are resolved they would be taken off the minutes and recorded off as resolved and move on. It is probably why we end up with meetings and actions on because people are unclear and you discover issues are bigger than what you thought. I guess that would be the most accurate way tracking it back through.
Sonia: If somebody emailed you and said there is a problem with this windows and it needs to be sorted within the next couple of weeks and then you send it to the right person to deal with. How would you track it to make sure it's solved? Because it is all done by email, how would you monitor it?
Design Manager: How would I manage it? Right, if it was via email I would leave the incoming email in my inbox because I go through and review what every couple of days is in my inbox. Well sometimes it gets a bit of out of control. What I do is I go through it so I

know I still need to reply to that email. This is where I have tried using that task bar to remind u but I don't know why I can't get my head round having to using it.
Sonia: Did you use to deal with any conversational threading?
Design Manager: I would sometimes search back through the emails on a conversation thread if in particular where you would try to find out where someone had said something or confirm something. Like you had a disagreement about something you would go back and find it.
Sonia: Was there a policy where you had to deal with one issue per email?
Design Manager: No, there was nothing like that.
Sonia: So you could mention different issues in one email.
Design Manager: Yeah.
Sonia: Have you ever used BIM before?
Design Manager: Yeah.
Sonia: So you are quite familiar with it.
Design Manager: We used it on the glass box on the side for the city library because it was so complicated we found it very difficult to just draw it in 2D. We used it in that but there was a policy in Ryder where all the new jobs had to go to Revit so everyone started training Revit. So it was really 4 years ago so quite early on. They were one of the practice to do that in Newcastle. And that was like hard you know. It was really difficult on teams because they had a couple of days training and they had to discover how to do things and there was no appreciation of how different it was to manage the process when you were using 3D modelling. Because at first it was like everyone tried to keep the same system and QA procedures and it was really difficult to keep track of it. After a while they realised it is different and we need to manage it differently. And here I teach the construction managers and project managers BIM so we look at all of these issues. What I'm aware of is that I think a lot of, especially if you read the marketing and stuff the students pick up that this is going to solve all of our issues in construction and this is not the case. I've heard about extranets, emails and all of these that come along in terms of IT will solve all of our problems but comes down to good management. So I've seen it sort of in that perspective what we are trying to do is to give students a good idea about what is going to happen in industry and realize that, you know get them to understand it so that they know what issues is going to face and how to manage those.
Sonia: Do you think BIM is going to have an affect on process and management of things, would have it any affects on communication practices as well?
Design Manager: Oh, yeah, it has to.
Sonia: It is going to bring decision making forward. There is going to be lots of RFI at early stages, I think.
Design Manager: Yeah, I mean it is, I don't know, it is the collaboration thing that is going to benefit. As in you know even now where you have got software that isn't compatible you have got services engineer redrawing in a different modelling software to try and calculate heat calculations and stuff like that and not having replication of that effort for everything is just fantastic. The amount of time it takes to do a door schedule for a complicate building that would take the architectural technologists good a few days to put one document to gether. Just to think you could do it straight off the model; it is absolutely brilliant, in terms of saving you from tasks. So I think it is really good in that sense. But what limits it is; who owns the model? Do you trust your colleagues in the design team to have a model that you have done and add to it and work collaboratively with it? How do you know if you give it to the service engineers they are not going to do something to damage the model? Or put in incorrect information that you are not responsible for? How do you know the structural information is right? It is a mind field. I think it is PI insurance that is keeping it from going any further. I think the idea of having project insurance rather than individual insurances is the only way forward. If you have a model and everyone works on it and nobody is worried about being caught out for responsibility. I think that is the only way it going to work. But clearly lawyers and insurance companies don't want us to have single project insurance because that is how they make a lot of money.
Sonia: That is all the questions I have got. I'm going to stop the recorder now.

APPENDIX F – FOCUS GROUPS AGENDA

Focus Group series

Agenda

12:30 PM------Welcome and Introduction followed by an interactive and fun ice breaker session

12:40 PM------Steve's talk on "introduction to BIM"

13:25 PM------Kicking off the focus group by dividing people in to 2 groups and ask them to:

a) Identify a rapporter
b) Identify a recorder
c) List out the type of organisation/people you communicate with specifically on construction projects.

d) How do you mostly communicate with these organisations? (what channels?)

e) What is the business reason you are communicating?

13:40 PM-------- Rapporters explain each group findings

13:55 PM-------- Summarizing by Steve

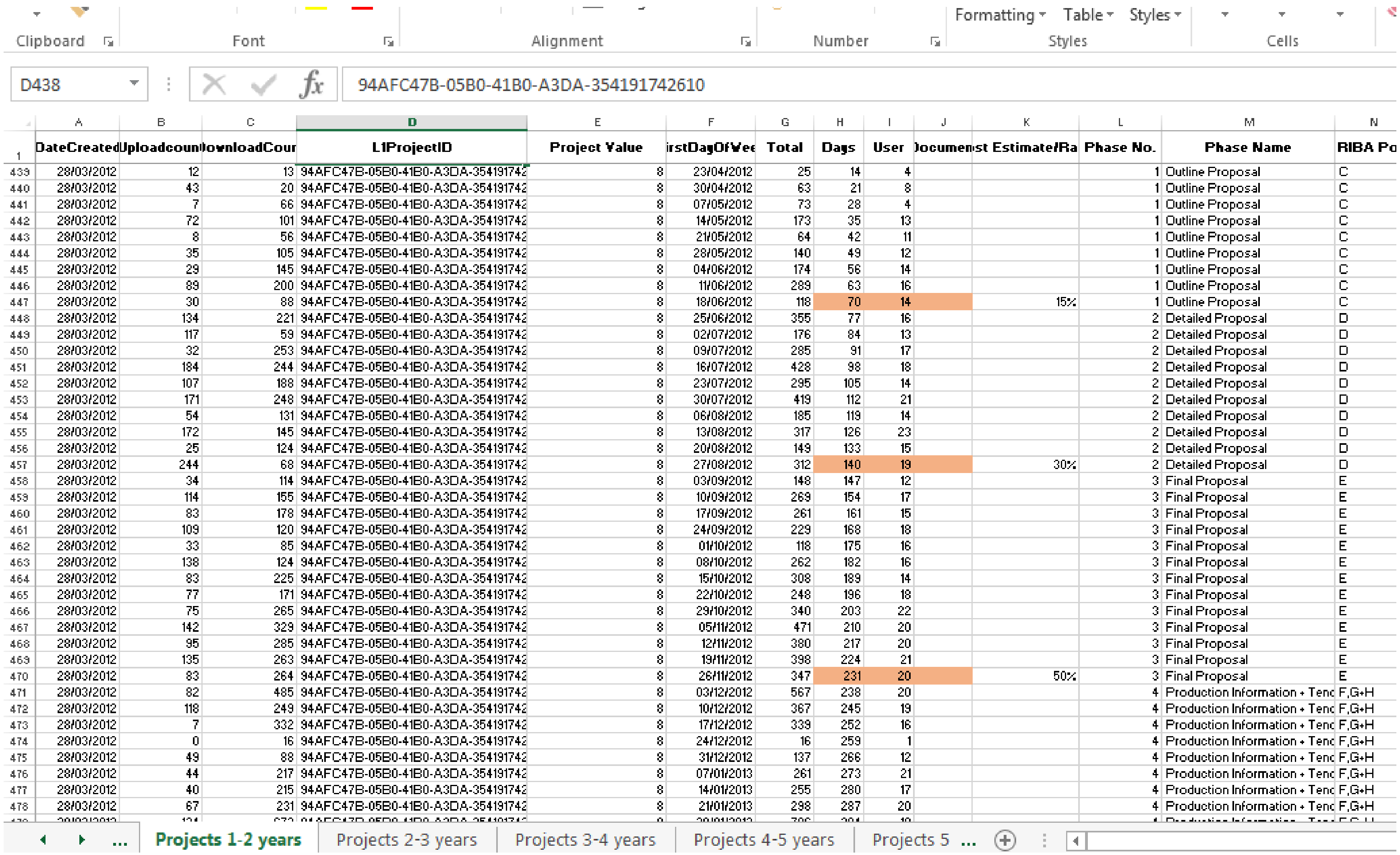
14:00 PM--------Open Forum

a) Where do you think your communication with the construction industry are having a negative impact on your business?
b) How could you change the way you communicate to add value to the business?

14:40 PM--------Summarizing the findings

15:00 PM--------Wrap Up & Adjourn

APPENDIX G – DATA MINING EXAMPLE - PROJECT PHASES



	DateCreated	Uploadcoun	DownloadCour	L1ProjectID	Project Value	irstDayOfWee	Total	Days	User	Documen	st Estimate/Ra	Phase No.	Phase Name	RIBA Po
439	28/03/2012	12	13	94AFC47B-05B0-41B0-A3DA-35419174	8	23/04/2012	25	14	4			1	Outline Proposal	C
440	28/03/2012	43	20	94AFC47B-05B0-41B0-A3DA-35419174	8	30/04/2012	63	21	8			1	Outline Proposal	C
441	28/03/2012	7	66	94AFC47B-05B0-41B0-A3DA-35419174	8	07/05/2012	73	28	4			1	Outline Proposal	C
442	28/03/2012	72	101	94AFC47B-05B0-41B0-A3DA-35419174	8	14/05/2012	173	35	13			1	Outline Proposal	C
443	28/03/2012	8	56	94AFC47B-05B0-41B0-A3DA-35419174	8	21/05/2012	64	42	11			1	Outline Proposal	C
444	28/03/2012	35	105	94AFC47B-05B0-41B0-A3DA-35419174	8	28/05/2012	140	49	12			1	Outline Proposal	C
445	28/03/2012	29	145	94AFC47B-05B0-41B0-A3DA-35419174	8	04/06/2012	174	56	14			1	Outline Proposal	C
446	28/03/2012	89	200	94AFC47B-05B0-41B0-A3DA-35419174	8	11/06/2012	289	63	16			1	Outline Proposal	C
447	28/03/2012	30	88	94AFC47B-05B0-41B0-A3DA-35419174	8	18/06/2012	118	70	14		15%	1	Outline Proposal	C
448	28/03/2012	134	221	94AFC47B-05B0-41B0-A3DA-35419174	8	25/06/2012	355	77	16			2	Detailed Proposal	D
449	28/03/2012	117	59	94AFC47B-05B0-41B0-A3DA-35419174	8	02/07/2012	176	84	13			2	Detailed Proposal	D
450	28/03/2012	32	253	94AFC47B-05B0-41B0-A3DA-35419174	8	09/07/2012	285	91	17			2	Detailed Proposal	D
451	28/03/2012	184	244	94AFC47B-05B0-41B0-A3DA-35419174	8	16/07/2012	428	98	18			2	Detailed Proposal	D
452	28/03/2012	107	188	94AFC47B-05B0-41B0-A3DA-35419174	8	23/07/2012	295	105	14			2	Detailed Proposal	D
453	28/03/2012	171	248	94AFC47B-05B0-41B0-A3DA-35419174	8	30/07/2012	419	112	21			2	Detailed Proposal	D
454	28/03/2012	54	131	94AFC47B-05B0-41B0-A3DA-35419174	8	06/08/2012	185	119	14			2	Detailed Proposal	D
455	28/03/2012	172	145	94AFC47B-05B0-41B0-A3DA-35419174	8	13/08/2012	317	126	23			2	Detailed Proposal	D
456	28/03/2012	25	124	94AFC47B-05B0-41B0-A3DA-35419174	8	20/08/2012	149	133	15			2	Detailed Proposal	D
457	28/03/2012	244	68	94AFC47B-05B0-41B0-A3DA-35419174	8	27/08/2012	312	140	19		30%	2	Detailed Proposal	D
458	28/03/2012	34	114	94AFC47B-05B0-41B0-A3DA-35419174	8	03/09/2012	148	147	12			3	Final Proposal	E
459	28/03/2012	114	155	94AFC47B-05B0-41B0-A3DA-35419174	8	10/09/2012	269	154	17			3	Final Proposal	E
460	28/03/2012	83	178	94AFC47B-05B0-41B0-A3DA-35419174	8	17/09/2012	261	161	15			3	Final Proposal	E
461	28/03/2012	109	120	94AFC47B-05B0-41B0-A3DA-35419174	8	24/09/2012	229	168	18			3	Final Proposal	E
462	28/03/2012	33	85	94AFC47B-05B0-41B0-A3DA-35419174	8	01/10/2012	118	175	16			3	Final Proposal	E
463	28/03/2012	138	124	94AFC47B-05B0-41B0-A3DA-35419174	8	08/10/2012	262	182	16			3	Final Proposal	E
464	28/03/2012	83	225	94AFC47B-05B0-41B0-A3DA-35419174	8	15/10/2012	308	189	14			3	Final Proposal	E
465	28/03/2012	77	171	94AFC47B-05B0-41B0-A3DA-35419174	8	22/10/2012	248	196	18			3	Final Proposal	E
466	28/03/2012	75	265	94AFC47B-05B0-41B0-A3DA-35419174	8	29/10/2012	340	203	22			3	Final Proposal	E
467	28/03/2012	142	329	94AFC47B-05B0-41B0-A3DA-35419174	8	05/11/2012	471	210	20			3	Final Proposal	E
468	28/03/2012	95	285	94AFC47B-05B0-41B0-A3DA-35419174	8	12/11/2012	380	217	20			3	Final Proposal	E
469	28/03/2012	135	263	94AFC47B-05B0-41B0-A3DA-35419174	8	19/11/2012	398	224	21			3	Final Proposal	E
470	28/03/2012	83	264	94AFC47B-05B0-41B0-A3DA-35419174	8	26/11/2012	347	231	20		50%	3	Final Proposal	E
471	28/03/2012	82	485	94AFC47B-05B0-41B0-A3DA-35419174	8	03/12/2012	567	238	20			4	Production Information + Tenc	F,G+H
472	28/03/2012	118	249	94AFC47B-05B0-41B0-A3DA-35419174	8	10/12/2012	367	245	19			4	Production Information + Tenc	F,G+H
473	28/03/2012	7	332	94AFC47B-05B0-41B0-A3DA-35419174	8	17/12/2012	339	252	16			4	Production Information + Tenc	F,G+H
474	28/03/2012	0	16	94AFC47B-05B0-41B0-A3DA-35419174	8	24/12/2012	16	259	1			4	Production Information + Tenc	F,G+H
475	28/03/2012	49	88	94AFC47B-05B0-41B0-A3DA-35419174	8	31/12/2012	137	266	12			4	Production Information + Tenc	F,G+H
476	28/03/2012	44	217	94AFC47B-05B0-41B0-A3DA-35419174	8	07/01/2013	261	273	21			4	Production Information + Tenc	F,G+H
477	28/03/2012	40	215	94AFC47B-05B0-41B0-A3DA-35419174	8	14/01/2013	255	280	17			4	Production Information + Tenc	F,G+H
478	28/03/2012	67	231	94AFC47B-05B0-41B0-A3DA-35419174	8	21/01/2013	298	287	20			4	Production Information + Tenc	F,G+H

APPENDIX H – EXAMPLES OF SQL QUERIES

```
SELECT
       Prj.DateCreated
       ,COUNT(C.ContainerId)AS Documents
       , Prj.L1ProjectID
       , dim.Date.FirstDayOfWeek
FROM
       dim3g.Container C
INNERJOIN dim3g.Container Prj
       ON C.L1ProjectID = Prj.ContainerIDSource
INNERJOIN dim.DateON
       dim.Date.DateKey =CAST(YEAR(C.DateCreated)ASVARCHAR(8))
             +RIGHT('0'+CAST(MONTH(C.DateCreated)ASVARCHAR(8)), 2)
             +RIGHT('0'+CAST(DAY(C.DateCreated)ASVARCHAR(8)), 2)
WHERE
       Prj.L1ProjectID ='64a2127b-fbd0-4460-a92f-345594333229'
       AND C.ContainerType ='Document'
GROUPBY
       Prj.DateCreated
       , Prj.L1ProjectID
       , dim.Date.FirstDayOfWeek
ORDERBY FirstDayOfWeek
```

```
SELECT L1ProjectID
       , [Week] =CAST(DATEPART(YEAR,CONVERT(date,STR(UpDown.DateKey),
112))ASCHAR(4))
             +'-'
             +CAST(DATEPART(ISO_WEEK,CONVERT(date,STR(UpDown.DateKey),
112))ASCHAR(2))
       ,SUM(UploadCount + DownloadCount)AS [Upload/Download Sum]
FROM
       dim3g.Container
INNERJOIN fact3g.UploadsAndDownloads AS UpDown
       ON Container.ContainerID = UpDown.ContainerID
WHERE
       ContainerType ='Project'
       ANDDATEDIFF(DD,DateCreated,JournalLastAccessedTimeIncChildren)>
364
       ANDStatus<>'DEL'
       AND JournalLastAccessedTimeIncChildren <'2013-06-30'
       AND JournalLastAccessedTimeIncChildren >'2000-01-01'
       AND L1ProjectID = ContainerIDSource
GROUPBY
       L1ProjectID,CAST(DATEPART(YEAR,CONVERT(date,STR(UpDown.DateKey),
112))ASCHAR(4))
             +'-'
             +CAST(DATEPART(ISO_WEEK,CONVERT(date,STR(UpDown.DateKey),
112))ASCHAR(2))
ORDERBY
L1ProjectID,CAST(DATEPART(YEAR,CONVERT(date,STR(UpDown.DateKey),
112))ASCHAR(4))
             +'-'
              +CAST(DATEPART(ISO_WEEK,CONVERT(date,STR(UpDown.DateKey),
```

Appendix I – Number of Information, Documents and Users across projects

		Mean	Std. Deviation	Minimum	Maximum
INFO	Project 1	87.18	61.585	8	302
	Project 2	119.15	126.684	1	589
	Project 3	273.91	128.196	67	614
	Project 4	71.71	41.261	2	193
	Project 5	141.98	102.772	3	401
	Project 6	131.62	94.038	1	399
	Project 7	162.95	140.151	2	556
	Project 8	280.45	137.981	13	796
	Project 9	408.95	165.670	2	746
	Project 10	87.75	74.616	1	312
	Project 11	103.90	73.986	2	315
	Project 12	476.21	212.314	24	914
	Project 13	213.18	929.162	1	5007
	Project 14	81.53	75.119	1	330
	Project 15	88.64	70.177	1	311
	Project 16	641.68	326.440	17	1381
	Project 17	633.27	339.145	2	1571
	Project 18	630.92	356.284	14	1413
	Project 19	98.09	63.246	1	304
	Project 20	184.77	93.563	14	409
	Project 21	353.06	448.553	8	2533
	Project 22	351.82	199.403	48	848
	Project 23	150.88	138.576	2	758
	Project 24	212.72	210.210	1	1427
	Project 25	349.19	324.094	1	1143
	Project 26	96.13	99.051	1	407
	Project 27	150.02	124.334	4	543
	Project 28	67.71	68.763	1	260
	Project 29	284.25	229.883	1	1096
	Project 30	350.21	313.511	1	1134
	Project 31	2904.20	2464.568	6	8800
	Project 32	355.22	435.694	1	1917
	Project 33	95.90	72.939	1	538
	Project 34	252.13	258.531	1	962
	Project 35	283.11	247.198	1	1191
	Project 36	503.88	274.831	2	1694
	Project 37	301.34	304.383	1	1512
	Project 38	375.28	417.054	1	1648
	Project 39	185.79	150.372	0	591
	Project 40	126.57	94.402	2	520
	Total	400.38	866.433	0	8800

		Mean	Std. Deviation	Minimum	Maximum
DOCUMENT	Project 1	15.59	19.391	0	73
	Project 2	15.24	25.000	0	126
	Project 3	57.82	40.117	10	199
	Project 4	10.28	16.091	0	106
	Project 5	11.64	14.667	0	60
	Project 6	29.88	27.229	0	168
	Project 7	16.64	21.257	0	105
	Project 8	16.13	4.745	1	24
	Project 9	66.39	46.958	1	332
	Project 10	8.52	11.991	0	50
	Project 11	8.13	18.015	0	105
	Project 12	49.48	39.226	0	175
	Project 13	189.84	852.359	0	4452
	Project 14	19.26	34.499	0	144
	Project 15	15.76	22.880	0	113
	Project 16	62.96	50.134	0	277
	Project 17	32.14	45.586	0	296
	Project 18	40.63	27.312	1	116
	Project 19	6.43	24.640	0	174
	Project 20	26.14	36.789	0	207
	Project 21	117.69	365.415	2	2516
	Project 22	22.75	34.945	0	168
	Project 23	9.44	17.691	0	144
	Project 24	15.23	59.677	0	501
	Project 25	26.79	33.469	0	201
	Project 26	10.19	27.561	0	227
	Project 27	10.87	21.304	0	143
	Project 28	8.29	17.191	0	102
	Project 29	47.55	106.274	0	1052
	Project 30	41.71	98.569	0	662
	Project 31	178.38	187.146	0	884
	Project 32	13.17	25.015	0	132
	Project 33	6.06	16.279	0	136
	Project 34	24.18	38.211	0	232
	Project 35	31.07	53.365	0	360
	Project 36	153.45	144.932	1	1042
	Project 37	46.04	71.076	0	351
	Project 38	27.71	45.022	0	295
	Project 39	11.93	33.724	0	318
	Project 40	14.92	22.171	0	129
	Total	42.97	134.657	0	4452

		Mean	Std. Deviation	Minimum	Maximum
USER	Project 1	6.64	2.681	1	12
	Project 2	5.80	2.511	1	12
	Project 3	12.22	2.545	4	18
	Project 4	7.46	2.599	1	13
	Project 5	9.84	4.665	2	18
	Project 6	8.60	3.733	1	16
	Project 7	10.73	4.619	1	21
	Project 8	16.13	4.745	1	24
	Project 9	13.48	3.722	1	19
	Project 10	7.00	3.796	1	14
	Project 11	6.84	2.870	1	12
	Project 12	22.54	8.302	3	37
	Project 13	2.22	1.295	1	8
	Project 14	5.37	3.200	1	14
	Project 15	6.69	3.059	1	13
	Project 16	22.71	6.937	1	35
	Project 17	18.63	5.493	1	27
	Project 18	33.20	12.937	1	54
	Project 19	7.65	2.782	1	13
	Project 20	11.34	4.240	2	20
	Project 21	16.97	7.274	1	50
	Project 22	17.20	5.477	6	27
	Project 23	10.86	5.101	1	20
	Project 24	10.93	7.167	1	26
	Project 25	12.85	9.151	1	34
	Project 26	6.70	4.292	1	16
	Project 27	9.71	4.775	1	18
	Project 28	4.90	3.081	1	11
	Project 29	13.53	7.732	1	28
	Project 30	15.59	10.066	1	36
	Project 31	81.97	60.035	2	174
	Project 32	11.53	11.285	1	36
	Project 33	7.36	3.110	1	16
	Project 34	10.68	8.088	1	26
	Project 35	14.77	9.249	1	32
	Project 36	30.16	10.265	1	51
	Project 37	13.46	10.280	1	34
	Project 38	15.90	12.608	1	41
	Project 39	9.87	6.073	1	22
	Project 40	15.03	6.222	1	32
	Total	16.90	22.698	1	174

Appendix J - Information Mean Value per Project Phase

Projects with 2-3 years duration

Phase 1	Mean	Std. Deviation
Project 23	50.61	55.304
Project 24	156.41	192.137
Project 25	237.59	219.940
Project 26	112.38	110.435
Project 27	259.00	168.171
Project 28	167.88	59.179
Project 29	111.94	270.785
Project 30	531.67	353.915
Total	200.96	244.490

Phase 2	Mean	Std. Deviation
Project 23	233.94	161.493
Project 24	380.24	148.863
Project 25	626.72	200.340
Project 26	170.47	88.830
Project 27	271.06	78.005
Project 28	110.71	53.869
Project 29	58.76	64.295
Project 30	804.00	179.118
Total	342.99	273.255

Phase 3	Mean	Std. Deviation
Project 23	312.26	130.116
Project 24	328.09	161.259
Project 25	697.26	256.055
Project 26	171.48	112.279
Project 27	182.00	83.081
Project 28	74.18	59.123
Project 29	215.95	159.183
Project 30	394.50	195.999
Total	313.31	237.053

Phase 4	Mean	Std. Deviation
Project 23	131.38	73.345
Project 24	188.95	100.876
Project 25	364.30	216.309
Project 26	67.81	40.198
Project 27	119.22	45.008
Project 28	38.90	21.016
Project 29	474.00	132.622
Project 30	263.84	162.594
Total	216.02	182.586

Projects with 2-3 years duration

Phase 5	Mean	Std. Deviation
Project 23	69.03	62.227
Project 24	101.81	249.909
Project 25	23.13	21.153
Project 26	18.32	29.311
Project 27	32.45	20.912
Project 28	9.62	10.038
Project 29	430.47	164.868
Project 30	67.69	66.092
Total	100.55	176.301

Phase 6	Mean	Std. Deviation
Project 23	73.67	41.356
Project 24	18.33	10.066
Project 25	10.00	5.000
Project 26	34.67	52.310
Project 27	12.00	11.358
Project 28	2.50	2.121
Project 29	191.33	43.662
Project 30	25.33	15.503
Total	47.87	65.500

Projects with 3-4 years duration

Phase 1	Mean	Std. Deviation	Std. Error
Project 31	1983.23	1737.380	312.043
Project 32	618.33	329.313	63.376
Project 33	44.42	33.698	6.609
Project 34	288.82	293.151	62.500
Project 35	52.00	52.739	10.343
Total	659.36	1146.176	99.762

Phase 2	Mean	Std. Deviation
Project 31	5916.16	1096.611
Project 32	1042.04	410.717
Project 33	80.50	56.639
Project 34	569.96	134.892
Project 35	251.65	149.876
Total	1790.64	2420.926

Phase 3	Mean	Std. Deviation	Std. Error
Project 31	5210.51	1182.589	184.689
Project 32	481.75	236.737	39.456
Project 33	76.29	50.930	8.609
Project 34	433.55	217.403	40.371
Project 35	485.38	232.095	39.804
Total	1501.26	2146.674	162.273

Phase 4	Mean	Std. Deviation
Project 31	3131.21	1309.073
Project 32	36.22	46.462
Project 33	133.38	65.844
Project 34	156.27	102.929
Project 35	491.35	205.750
Total	901.95	1414.993

Phase 5	Mean	Std. Deviation	Std. Error
Project 31	187.14	241.243	31.953
Project 32	15.44	18.592	2.683
Project 33	110.85	85.776	12.512
Project 34	20.24	23.145	3.615
Project 35	160.36	167.083	24.372
Total	104.10	160.138	10.337

Phase 6	Mean	Std. Deviation
Project 31	62.00	46.785
Project 32	10.60	10.359
Project 33	185.40	111.700
Project 34	3.50	2.380
Project 35	10.80	11.323
Total	56.80	85.945

Projects with 4-5 years duration

Phase 1	Mean	Std. Deviation	Std. Error
Project 36	344.94	317.729	54.490
Project 37	404.04	391.219	73.933
Project 38	147.61	164.433	29.533
Project 39	262.75	143.348	35.837
Project 40	85.26	72.927	12.507
Total	242.80	277.975	23.245

Phase 2	Mean	Std. Deviation
Project 36	670.64	309.695
Project 37	656.82	153.612
Project 38	684.10	303.222
Project 39	254.24	112.999
Project 40	110.12	71.059
Total	486.70	332.407

Phase 3	Mean	Std. Deviation	Std. Error
Project 36	455.87	181.738	27.092
Project 37	485.97	170.176	27.977
Project 38	913.62	333.621	51.479
Project 39	322.29	112.709	24.595
Project 40	149.93	98.662	14.708
Total	475.69	334.027	24.233

Phase 4	Mean	Std. Deviation
Project 36	406.02	157.105
Project 37	204.97	186.104
Project 38	288.49	276.306
Project 39	183.09	104.439
Project 40	87.04	80.357
Total	241.02	210.988

Phase 5	Mean	Std. Deviation	Std. Error
Project 36	599.03	271.099	34.999
Project 37	14.82	18.224	2.577
Project 38	27.85	22.654	3.055
Project 39	24.86	20.128	3.738
Project 40	167.35	105.253	13.588
Total	192.82	273.201	17.142

Phase 6	Mean	Std. Deviation
Project 36	625.86	329.214
Project 37	6.50	4.135
Project 38	17.00	22.423
Project 39	7.33	5.508
Project 40	161.57	54.203
Total	195.69	298.018

Appendix K – Document Mean Value per Project Phase

Projects with 2-3 years duration

Phase 1	Mean	Std. Deviation	Std. Error
Project 23	13.11	16.862	3.975
Project 24	32.53	120.886	29.319
Project 25	38.82	48.100	11.666
Project 26	31.25	60.869	15.217
Project 27	38.53	39.592	9.602
Project 28	32.75	31.576	11.164
Project 29	88.94	264.188	66.047
Project 30	179.93	178.133	45.994
Total	56.35	132.794	11.925

Phase 2	Mean	Std. Deviation	Std. Error
Project 23	20.41	33.860	8.212
Project 24	18.53	18.232	4.422
Project 25	48.89	29.502	6.954
Project 26	10.87	19.168	4.949
Project 27	15.72	9.737	2.295
Project 28	11.86	5.757	2.176
Project 29	10.47	13.942	3.382
Project 30	64.93	85.413	22.827
Total	25.67	39.079	3.524

Phase 3	Mean	Std. Deviation	Std. Error
Project 23	13.09	15.168	3.163
Project 24	19.22	29.593	6.170
Project 25	54.61	27.319	5.696
Project 26	11.76	14.078	3.072
Project 27	10.74	16.316	3.402
Project 28	5.09	10.492	3.164
Project 29	22.36	24.082	5.134
Project 30	14.30	17.281	3.864
Total	20.04	25.202	1.956

Phase 4	Mean	Std. Deviation	Std. Error
Project 23	4.46	5.158	1.053
Project 24	2.05	3.823	.815
Project 25	13.57	10.426	2.174
Project 26	6.95	12.302	2.685
Project 27	2.22	3.219	.671
Project 28	1.50	3.064	.969
Project 29	42.29	26.209	5.719
Project 30	7.84	19.463	4.465
Total	10.51	18.236	1.428

3-4 years projects

Phase 1	Mean	Std. Deviation	Std. Error
Project 31	197.45	200.314	35.977
Project 32	43.48	35.003	6.736
Project 33	7.31	11.540	2.263
Project 34	58.82	66.630	14.206
Project 35	19.31	40.657	7.974
Total	70.31	125.637	10.935

Phase 2	Mean	Std. Deviation	Std. Error
Project 31	380.09	95.187	16.827
Project 32	22.12	15.731	3.085
Project 33	3.77	5.339	1.047
Project 34	44.30	32.711	6.821
Project 35	62.08	84.698	16.611
Total	116.31	162.205	14.065

Phase 3	Mean	Std. Deviation	Std. Error
Project 31	243.78	171.867	26.841
Project 32	16.53	29.281	4.880
Project 33	1.20	2.495	.422
Project 34	26.72	25.858	4.802
Project 35	48.62	57.811	9.914
Total	74.63	129.403	9.782

Phase 4	Mean	Std. Deviation	Std. Error
Project 31	200.07	176.041	27.164
Project 32	.03	.167	.028
Project 33	7.91	17.046	2.923
Project 34	17.17	24.151	4.409
Project 35	32.71	36.787	6.309
Total	58.52	118.744	8.951

Phase 5	Mean	Std. Deviation	Std. Error
Project 31	10.53	27.652	3.663
Project 32	.00	.000	.000
Project 33	6.28	17.184	2.507
Project 34	.00	.000	.000
Project 35	9.85	31.700	4.624
Total	5.66	21.225	1.370

Phase 6	Mean	Std. Deviation	Std. Error
Project 31	.00	.000	.000
Project 32	.00	.000	.000
Project 33	31.00	59.000	26.386
Project 34	.00	.000	.000
Project 35	.00	.000	.000
Total	6.20	27.209	5.442

4-5 Years projects

Phase 1	Mean	Std. Deviation	Std. Error
Project 36	137.18	159.971	27.435
Project 37	111.25	101.032	19.093
Project 38	30.81	33.695	6.052
Project 39	41.25	81.124	20.281
Project 40	19.47	28.217	4.839
Total	70.32	107.069	8.954

Phase 2	Mean	Std. Deviation	Std. Error
Project 36	178.97	190.758	33.207
Project 37	109.07	59.079	11.165
Project 38	58.73	60.308	11.011
Project 39	11.12	7.793	1.890
Project 40	18.18	29.558	5.069
Total	81.19	118.047	9.906

Phase 3	Mean	Std. Deviation	Std. Error
Project 36	111.11	91.776	13.681
Project 37	34.38	35.801	5.886
Project 38	65.95	51.254	7.909
Project 39	11.14	7.996	1.745
Project 40	18.44	21.992	3.278
Total	53.19	65.440	4.748

Phase 4	Mean	Std. Deviation	Std. Error
Project 36	126.07	93.718	13.818
Project 37	30.05	65.829	10.822
Project 38	4.71	13.408	2.094
Project 39	9.27	10.366	2.210
Project 40	4.87	8.701	1.297
Total	39.41	73.832	5.342

Phase 5	Mean	Std. Deviation	Std. Error
Project 36	191.85	163.093	21.055
Project 37	.22	1.556	.220
Project 38	.02	.135	.018
Project 39	.03	.186	.034
Project 40	14.90	19.445	2.510
Total	48.89	112.576	7.064

Phase 6	Mean	Std. Deviation	Std. Error
Project 36	235.14	115.595	43.691
Project 37	.00	.000	.000
Project 38	.00	.000	.000
Project 39	.00	.000	.000
Project 40	19.14	17.276	6.530
Total	61.38	113.754	21.124

APPENDIX L – CORRELATION BETWEEN AMOUNT OF INFORMATION EXCHANGED AND NUMBER OF USERS

Project 11	**User**
Information	.606**

Project 12	**User**
Information	.797**

Project 13	**User**
Information	.493**

Project 14	**User**
Information	.597**

01

Project 15	**User**
Information	.657**

Project 16	**User**
Information	.731**

Project 17	**User**
Information	.504**

Project 18	**User**
Information	.774**

Project 19	**User**
Information	.457**

Project 20	**User**
Information	.627**

Project 21	**User**
Information	.631**

Project 22	**User**
Information	.771**

Project 23	**User**
Information	.769**

Project 24	**User**
Information	.523**

Project 25	**User**

Information	.885**

Project 26	User
Information	.754**

Project 27	User
Information	.731**

Project 28	User
Information	.785**

Project 29	User
Information	.737**

Project 30	User
Information	.814**

Project 31	User
Information	.933**

Project 32	User
Information	.919**

Project 33	User
Information	.478**

Project 34	User
Information	.902**

Project 35	User
Information	.845**

Project 36	User
Information	.456**

Project 37	User
Information	.831**

Project 38	User
Information	.902**

Project 39	User
Information	.792**

Project 40	User
Information	.731**

Appendix M – Correlation between amount of Documents Created and number of Users

Project 11	User
Document	-.255*

Project 12	User
Document	.079

Project 13	User
Document	.505**

Project 14	User
Document	.233

Project 15	User
Document	.062

Project 16	User
Document	.242*

Project 17	User
Document	-.218

Project 18	User
Document	.477**

Project 19	User
Document	-.133

Project 20	User
Document	-.202

Project 21	User
Document	.535**

Project 22	User
Document	.376**

Project 23	User
Document	.243**

Project 24	User
Document	-.025

Project 25	User
Document	.542**

Project 26	User
Document	.239*

Project 27	User
Document	.309**

Project 28	User
Document	.420**

Project 29	User
Document	.094

Project 30	User
Document	.159

Project 31	User
Document	.591**

Project 32	User
Document	.568**

Project 33	User
Document	.126

Project 34	User
Document	.530**

Project 35	User
Document	.209**

Project 36	User
Document	-.056

Project 37	User

Document	.339**

Project 38	User
Document	.586**

Project 39	User
Document	.093**

Project 40	User
Document	.235**

Appendix N – Regression between amount of Information Exchanged and Users

Project 10

	b	SE B	β	p
Constant	-22.098	11.858		.067
User	15.693	1.492	.798	.000

Note, R^2_{adj}= .637; F(1,63)=110.669, *p*<.001.

Project 11

	b	SE B	β	p
Constant	-3.023	19.603		.878
User	15.635	2.646	.606	.000

Note, R^2_{adj}= .368; F(1,60)=34.909, *p*<.001.

Project 12

	b	SE B	β	p
Constant	16.617	45.937		.719
User	20.392	1.914	.797	.000

Note, R^2_{adj}= .636; F(1,65)=113.475, *p*<.001.

Project 13

	b	SE B	β	p
Constant	-574.069	233.680		.018
User	353.902	91.016	.493	.000

Note, R^2_{adj}= .243; F(1,47)=15.119, *p*<.001.

Project 14

	b	SE B	β	p
Constant	6.285	15.173		.680
User	14.010	2.432	.597	.000

Note, R^2_{adj}= .356; F(1,60)=33.180, *p*<.001.

Project 15

	b	SE B	β	p
Constant	-12.166	19.366		.533
User	15.071	2.638	.657	.000

Note, R^2_{adj}= .431; F(1,43)=32.637, *p*<.001.

Project 16

	b	SE B	β	p
Constant	-140.046	93.030		.137
User	34.422	3.920	.731	.000

Note, R^2_{adj}= .535; F(1,67)=77.102, *p*<.001.

Project 17

	b	SE B	β	p
Constant	53.820	131.431		.684
User	31.111	6.773	.504	.000

Note, R^2_{adj}= .254; F(1,62)=21.101, *p*<.001.

Project 18

	b	SE B	β	p
Constant	-76.703	82.235		.355
User	21.312	2.310	.774	.000

Note, R^2_{adj}= .599; F(1,57)=85.094, *p*<.001.

Project 19

	b	SE B	β	p
Constant	18.636	22.793		.417
User	10.389	2.804	.457	.001

Note, R^2_{adj}= .209; F(1,52)=13.731, *p*<.001.

Project 20

	b	SE B	β	p
Constant	27.792	26.182		.293
User	13.845	2.165	.627	.000

Note, R^2_{adj}= .394; F(1,63)=40.896, *p*<.001.

Project 21

	b	SE B	β	p
Constant	-307.306	109.429		.007
User	38.913	5.934	.631	.000

Note, R^2_{adj}= .398; F(1,65)=43.008, *p*<.001.

Project 22

	b	SE B	β	p
Constant	-130.711	54.968		.021
User	28.054	3.048	.771	.000

Note, R^2_{adj}= .594; F(1,58)=84.742, *p*<.001.

Project 23

	b	SE B	β	p
Constant	-75.984	19.433		.000
User	20.884	1.621	.769	.000

Note, R^2_{adj}= .591; F(1,115)=166.067, *p*<.001.

Project 24

	b	SE B	β	p
Constant	44.943	30.960		.149
User	15.351	2.372	.523	.000

Note, R^2_{adj}= .274; F(1,111)=41.882, *p*<.001.

Project 25

	b	SE B	β	p
Constant	-53.529	24.364		.030
User	31.332	1.546	.885	.000

Note, R^2_{adj}= .783; F(1,114)=410.524, *p*<.001.

Project 26

	b	SE B	β	p
Constant	-20.449	11.933		.090

User	17.394	1.501	.754	.000

Note, R^2_{adj}= .568; F(1,102)=134.211, *p*<.001.

Project 27

	b	SE B	β	p
Constant	-34.932	18.066		.056
User	19.041	1.671	.731	.000

Note, R^2_{adj}= .535; F(1,113)=129.915, *p*<.001.

Project 28

	b	SE B	β	p
Constant	-18.178	11.407		.117
User	17.520	1.976	.785	.000

Note, R^2_{adj}= .616; F(1,49)=78.632, *p*<.001.

Project 29

	b	SE B	β	p
Constant	-12.385	30.227		.683
User	21.921	1.942	.737	.000

Note, R^2_{adj}= .544; F(1,107)=127.463, *p*<.001.

Project 30

	b	SE B	β	p
Constant	-44.926	34.396		.195
User	25.349	1.857	.814	.000

Note, R^2_{adj}= .662; F(1,95)=186.433, *p*<.001.

Project 31

	b	SE B	β	p
Constant	-235.556	104.171		.025
User	38.305	1.026	.933	.000

Note, R^2_{adj}= .871; F(1,207)=1393.454, *p*<.001.

Project 32

	b	SE B	β	p
Constant	-53.944	18.502		.004
User	35.475	1.148	.919	.000

Note, R^2_{adj}= .844; F(1,176)=954.683, *p*<.001.

Project 33

	b	SE B	β	p
Constant	13.349	12.576		.290
User	11.218	1.575	.478	.000

Note, R^2_{adj}= .229; F(1,171)=50.737, *p*<.001.

Project 34

	b	SE B	β	p
Constant	-55.768	15.266		.000
User	28.818	1.141	.902	.000

Note, R^2_{adj}= .813; F(1,147)=638.375, *p*<.001.

Project 35

	b	SE B	β	p
Constant	-50.496	19.075		.009
User	22.591	1.096	.845	.000

Note, R^2_{adj}= .714; F(1,170)=425.163, *p*<.001.

Project 36

	b	SE B	β	p
Constant	135.565	50.821		.008
User	12.212	1.596	.456	.000

Note, R^2_{adj}= .208; F(1,223)=58.580, *p*<.001.

Project 37

	b	SE B	β	p
Constant	-30.065	20.526		.145

User	24.617	1.213	.831	.000

Note, R^2_{adj}= .691; F(1,184)=411.879, *p*<.001.

Project 38

	b	SE B	β	p
Constant	-99.392	20.283		.145
User	29.849	1.000	.902	.000

Note, R^2_{adj}= .814; F(1,203)=890.303, *p*<.001.

Project 39

	b	SE B	β	p
Constant	-7.689	17.008		.652
User	19.602	1.469	.792	.000

Note, R^2_{adj}= .627; F(1,106)=177.942, *p*<.001.

Project 40

	b	SE B	β	p
Constant	-40.166	11.266		.000
User	11.096	0.693	.731	.000

Note, R^2_{adj}= .535; F(1,223)=256.440, *p*<.001.