Towards a more efficient collaborative working in design and construction teams via enhancing electronic communications and employing Building Information Modelling

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1. Introduction

1.1 Human Society and Complex Working Environments

As a species, we are social beings who live out our lives in the company of other humans. We organize 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 socialization with deliberate changes in social behaviour and organization 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.

Today, modern society has become so complex and isolated that no one can entirely study it any longer and many people do not know what role their work plays in the overall schemes of things (Aalst & Hee 2004). This complexity and isolation is a major social dilemma which is also seen in AEC/FM industry. Complexity of projects and various activities within the industry necessitates engaging diverse organisations, roles and partnerships, sometimes globally to create a communication network (Anumba *et al.* 1997; Emmitt & Gorse 2003). 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.

However, rapid development of IT over the last decade has produced various technological innovations to create, transfer and store information (Emmitt & Gorse 2003). As well, increasing number of people are connecting to the internet as the world moves into a new age of globalisation. "*The Internet has revolutionized the computer and communications world like nothing before*" (Leiner *et al*. 2009). The Internet provides a means of information distribution, communication, collaboration and individual interactions via computers devoid of location (Leiner *et al*. 2009).

In terms of technology and IT, construction has been undergoing significant changes since the late 80's. The governmental work done by Latham and Egan and the reports published by them; Emerson 1962, Latham 1994 and Egan 1998 and 2002, in regards to Culture, Practice and Technology change were introduced in the 90s which are the major changes within the industry. As technology grows rapidly in construction industry, better use is anticipated to be made of it to have an impact on traditional business processes and develop more efficient collaborative workflows.

2. Literature Review

2.1Traditional Method of Design Communication

Construction projects are heavily document-oriented (Mao, Zhu & Ahmad 2006). People involved in a project, from the client start up until the closure of the project and facility management, organise specialized information that others will use. The traditional means of communication in construction was to manually create 2D drawings, which are just geometric shapes but with no intelligence, and communicate them from initial stage of design to client approval and construction.

Review of the literature indicates that the construction industry has shifted from traditional method of 2D paper-based documents to electronic-based means of communication using Computer Aided Design technology. There are services such as e-mail, extranet sites and FTP links to provide immediate access and up to date 2D CAD documents.

The shift from paper-based communication to electronic-based communication has also changed the construction culture. People have adopted two ways of working practices which includes different ways of communicating:

- Informal working practices are at an organisational level which includes the organisational culture and the ways in which people have adopted their ways of working and feel most comfortable at. The following methods of communication are used for updating, requesting information and any other problems there is internally within an organisation.
    - E-mail - it is written simple and informal. Usually if there is an issue with a document, it gets sent via e-mail before it goes for an approval.
    - Phone
    - Face-face Discussion/ Regular Meetings

- Formal working practices are at a project level which includes procurement methods and all the formal procedures. The following methods of communication are used for stage approvals, management, contacting other stakeholders and request for change within a project team.
    - E-mail – has the same implications as a letter when written in a management level.
    - Extranet Site – only drawings and documents that are up to date and their context and sensitivity have been checked and approved by the project manager get published on the site.

According to Latham (1994) effective communication is vital for properly functioning of construction projects and failing to communicate will result in low quality and productivity.

Inaccuracy and errors in traditional procurement and communication methods has been criticized for 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 (Anumba *et al.* 1997; Latham 1994, Eastman *et al.* 2008). New organisational structure, contractual approach and use of more advanced project extranets and electronic document management systems were introduced to conquer these problems. Nonetheless these methods have done little to reduce the brutality of conflicts caused by electronic-based communication. Successful governmental reports (Emerson 1962; Latham 1994; Egan 1998, 2002) accentuate the lack of effective co-ordination and communication and the need for integration.

2.2 A Picture is a 1000's Word

People involved in a construction project work together to accomplish a goal without the use of face to face interaction and through Computer Supported Cooperative Work and Computer Mediated Communication which are examples of Virtual Collaboration. Virtual collaboration supports collaborative geographically dispersed participants in both synchronous and asynchronous time. E-mail is an asynchronous application which has become the main channel for distributing documentary information, supporting collaboration and personal and business interactions between individuals. It is the fastest, easiest and most efficient way to communicate and update other stakeholders; therefore it has become the central part of communication workflow.

However e-mail does have some limitations. The average volume of incoming e-mail is from 40 to 150 e-mails per day. This has made e-mail become a task in its own rights with time allocated to do it. Peer to peer communication predominates and ease use of e-mail has let people send e-mails 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-mails per day, only because the sender can easily send an e-mail and think they have done their job, will cost massively in terms of time and effort. All e-mails would be demanding some input and some thought which will need consideration time. So e-mails are quite costly to the receiver which will reduce the efficiency and quality of the team. Even though e-mail is now the main means of information and document exchange, still there are many limitations for file transfer. File sizes are too large and attachments clog the inbox. Due to large file sizes, information from the sender must be abbreviated and summarized to a level that facilitates the transmission, i.e. messages (drawings or documents) larger than a certain size are rejected by the server and bounce back. Therefore, some information must be reconstructed from the e-mail message, hence the greater the level of summarization, the greater the potential for error during reconstruction. This will result in time and effort being wasted.

Visual communication however will enhance the reconstruction of information. This is why there has been so much development in the area of object oriented technology. "*Objects are*

software entities that combine data structures and operations on the data. Together, these enable groups of objects to model real-world entities based on their characteristics (represented by data elements) and their behaviour (represented by data manipulation operations). In this way, objects can model concrete things such as people, data entry forms and abstractions such as numbers or geometrical concepts". This will create a live client-server environment with a central model server to enhance collaboration and Integrated Project Delivery between design teams. IPD is a collaborative procurement method that can be applied to construction projects to reduce time and waste and increase efficiency through all stages of design, fabrication and construction.

2.3 BIM Method of Design Communication

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 and consistent technology for handling structured data which enables the visualisation and development of 3D spatial models of buildings and intelligent objects. BIM 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. "*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). With the emergent use of BIM, the communications and their content will refer to spatial entities and specification which will have an effect on the information exchange. "*A BIM environment would reduce the resistance to data exploration and interaction by reducing the effort required to access and display increasingly large amounts of information*" (Peri No Date).

2.4 Integration of BIM and E-mail

Project-oriented interactions patterns will have to be supported by next generation information systems including BIM which will have to support smooth interaction with a large applications running on different platforms and distributed information networks.
Project participants will have to send BIM files or refer to entities and components of a building of a model. BIM files are too large to be transferred via e-mail and if made any smaller, information will be lost.

That is why currently people are referring to building components in a building model by exporting BIM files as PDF files and sending them as attachments via e-mail. The recipient then has to spend some time looking for the component in the model. Not only time and effort is wasted, also because they might be running the model on a different platform, that

particular component might be named differently or placed at a different location. This is all because of lack of interoperability between BIM models which duplicates information; therefore BIM will increase e-mail communication and make users are overloaded with information. Alvin Toffler 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. Users need relevant and significant information, not bewildering amounts of information.

E-mail effectiveness is not scalable enough to meet the future increase in communication brought about by BIM. The whole point of BIM is to have a collaboration scenario with one central workspace. This is why there is a need to integrate BIM and E-mail by developing a Model View Definition (Communication View). By using industry standards such as Industry Foundation Classes (IFC) it is technically feasible to develop such a method.

So is construction industry ready for a change in their communication practices? Is it ready for a BIM-based communication workflow? Or even a communication strategy in general? So far, researchers have mainly focused on the adoption rate, process improvement, disadvantages and advantages of BIM. Little attention has been given to visualising the existing patterns of communication and the importance of BIM and the significant affects it will have on effective collaboration and communication. Therefore, the purpose of this study is to develop schema outlining different types of metadata. Metadata will play a crucial role to assist in the location of the information and in describing the content of e-mails to improve access to resources. Metadata facilitates the integration between BIM and e-mail. It can also be used to automatically extract and reformat the information from a BIM model. This framework will also promote interoperability which will allow multiple systems with different platforms and data structures to exchange information with minimum loss of content.

3. Aims and Objectives

The aim of this research is:

To develop a BIM-based communication workflow to support collaborative processes between design and construction teams.
The objectives are: (please see appendix A)

- Create Conceptual and Cognitive maps of existing communication practices to visualise the existing patterns.
- Determine the relationship between data mining e-mails and 3D information models.
- Develop a metadata framework to facilitate the integration between BIM and E-mail.
- Test the developed metadata framework on a number of key BIM users and improve the existing communication workflow processes around BIM models.

4. Methodology

4.1 Constructivism

This research aligns with constructivist thinking which is based on epistemology paradigm and adopts a qualitative approach driven by a main case study (please see appendix B). Constructivism is based on previous experience and derived knowledge and understanding of the world's phenomenon (Bryman 2008). The author is a unique individual with a background in Computer Science and Information Systems, so construction industry and the working practices are fairly new with many unknowns. But, the researcher has already got some ideas and understanding of how people and systems work in industry. Therefore as the study proceeds, the researcher engages in the process of improving the prior knowledge through new experiences.

As well, 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. For this reason the approach to this study is largely inductive and exploratory that addresses group and personal communication patterns and identifies techniques in light of CMC and CSCW to discover principles and facts. The approach is going to be an iterative process where a set of prototypes are released and in the end evolve into a complete result. A literature review will be carried out in the first year of the research to establish a conceptual map of key issues relating to electronic communication platforms, BIM processes and technologies. A pilot study will be done whilst a literature review is carried out just to better understand the current practices in construction. After completion of the pilot study a case study will be carried out. The case study sets out to build on the experience of 4projects and Northumbria University to overcome the many barriers in electronic communication and integration of e-mail and BIM.

4.2 Pilot Study

It is essential to gather information about the current working and communication practices to understand the nature of the problem. Hence a pilot study has been conducted between January and March 2011, prior to the case study, for the first trial run of data collection. The main objective of the pilot study was to identify and understand existing electronic communication patterns and enable a critical evaluation of construction dynamics. This part of the research was purely inductive as it was moving from an explicit observation to generalisation and hypothesis creation. This was a vital part of data collection that resulted in creating a conceptual map of existing e-communication practices.

Due to the qualitative nature of the study and to achieve consistent data, a small sample was selected among project consultants and engineers to be interviewed. Sampling can be used as a technique to reduce the amount of data that need to be collected as well as generalization about all similar cases (Saunders *et al*., 2003; Sekaran & Bougie, 2010). Individual practitioners in the sample were chosen because they:

- ✓ Have many years of experience in industry
- ✓ Come from different backgrounds with different specialities
- ✓ Are completely familiar with the construction culture and environment
- ✓ Have minimum level of using electronic communication systems
- ✓ Have 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. Interviews cede people's experiences, opinions and knowledge (Patton, 2002). It enables participants to share their individual perspectives to allow the author to observe and construct an understanding of current communication practices and the ways in which people are working in the course of a construction project that are not already explained.

A series of keywords and questions was prepared before the interview; however the interviews were more like a conversation rather than an interview. This gives interviewees the chance to point out situations which have not been identified by the researcher.

4.3 Analysis

In the analysis stage, all interviews were tape-recorded and listened to once finished. They were all transcribed accurately and accordingly afterwards. The transcriptions were used for further in-depth data analysis using Semantic Text Analysis tools. Nvivo 8 was 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. The researcher's lines were removed from the transcriptions. Initially, all transcriptions were uploaded onto the software individually then they were all combined as one big textual data and were uploaded.

This method of analysis which is based on Template Analysis phenomena helped the researcher classify significant patterns and produce a list of codes representing the themes identified in the textual data (King, 2004). Some of these codes were identified prior to the study but they were modified and added by progressing through the transcripts (King, 2004). Template analysis works mainly well to compare the views of different groups or roles within a specific context and to develop a conceptual map (King, 2004: 257). Four main categories emerged from the analysis:

- ➢ Communication
- ➢ Information
- ➢ People
- ➢ Project

4.4 Mapping

Cognitive mapping technique was used for every single transcription to represent individual's knowledge about the four main categories. Cognitive mapping 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). It is causal based and 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 interviewee's statements linking to the appropriate concept (please see appendix C).

After completion all the maps were compared to discover the variables and relationships between them that affect the electronic communication systems. Main variables which had a direct affect on communication systems were as follow:

- Information
- People
- Project

Main variables that emerged from the maps are the same as the main categorise from template analysis. Cognitive maps were quite complex and not easy to understand so the common events and activities in all the maps were identified to draw a basic and general concept map to visualize the situation. Thus, four different concept maps (appendix D) were drawn based on the four main categories.

4.5 Case Study

Next step of this study is to do a case study at 4projects using both theirs and Northumbria's resources to look into building models. It is assumed that there are related references between unstructured e-mail contents and building components and project information. These references are assumed to be constant in almost all the e-mails which will form some sort of structure. So the purpose of this case study is to develop a metadata framework as a link to connect the unstructured e-mail content to BIM to improve communication protocols, decision audit trail and also to reduce information overload. 4projects will allow access to data mining emails in a range of companies to determine relationships to 3D information models.

First step of the case study would be to study 4project's database template to identify different fields for adding or searching documents. Once the common fields are identified then find the keywords or phrases that people put in each field by using word count to either search or create a new document to verify the metadata tags on them. After that, find out from key users of e-mail and BIM, the ways in which people are communicating around a BIM model currently and discuss the requirements needed to communicate around a building model. Based on these requirements develop a mark up language (metadata framework) and a pilot piece of software that would be a plug in to Revit to extract the relevant data. Then apply the metadata towards unstructured communications (e-mails) related to building components and link them to construction process or project management information via industry standards like IFCs. Metadata's are going to be stored in an IFC database and linked to both the objects described and the project information. This would be the integration of

BIM and E-mail which would visualise and automate the process of extraction and reformation of information. Last step would be to do a number of tests with the key users again to see if the integration enhances e-mail communication and improves operational management.

Conclusion

Construction paradigm has shifted from paper-based documents to electronic-based documents. Because of this the vision of this project is to develop new thinking concerning how we communicate electronically. This is to enhance collaboration in light of Computer Mediated Communication and Computer Supported Collaborative Work amongst project teams to reduce time and effort being wasted.

Construction is moving towards Integrated Project Delivery (IPD) to reduce cost and time and provide better quality. BIM technology is closely related to IPD and they will both change the traditional procurement methods and dynamics of a project workflow. BIM will enable project stakeholders and important roles to collaborate more effectively and apply their expertise as early as possible which will increase on time decision-making abilities. However, BIM is not currently being used as a live model, therefore BIM has created more communication and files are being extracted and exchanged by e-mail as excel and drawing file attachments. But e-mail is not an effective means of communication and due to the limitations of an e-mail system, BIM files must be condensed to a level that facilitates the transmission. Hence, metadata related to these attachments would be relevant to any other files. Metadata is vital for project management and to track communication to easily find where everything was or what happened to it during the project life cycle. It is to ensure that information is monitored, archived and can be easily accessed in the lifecycle of the project.

Study of enhanced collaboration in construction is not new. 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 either the BIM model or the E-mail system. This way 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.

To conclude; there is a need to increase the cost of sending e-mails and decrease the cost of receiving them which will generate a net reduction, better quality and efficient responses. Also to create the potential for new communication mechanisms which are spatially aware and sympathetic to the working practices of the construction industry in order to enhance communication protocols, decision audit trail and also to reduce information overload. Construction needs an integrated BIM-based communication and collaboration workflow with a central workspace environment. This is to create an extension of IFC format that

supports project communication and collaboration without having to exchange the 3D models.

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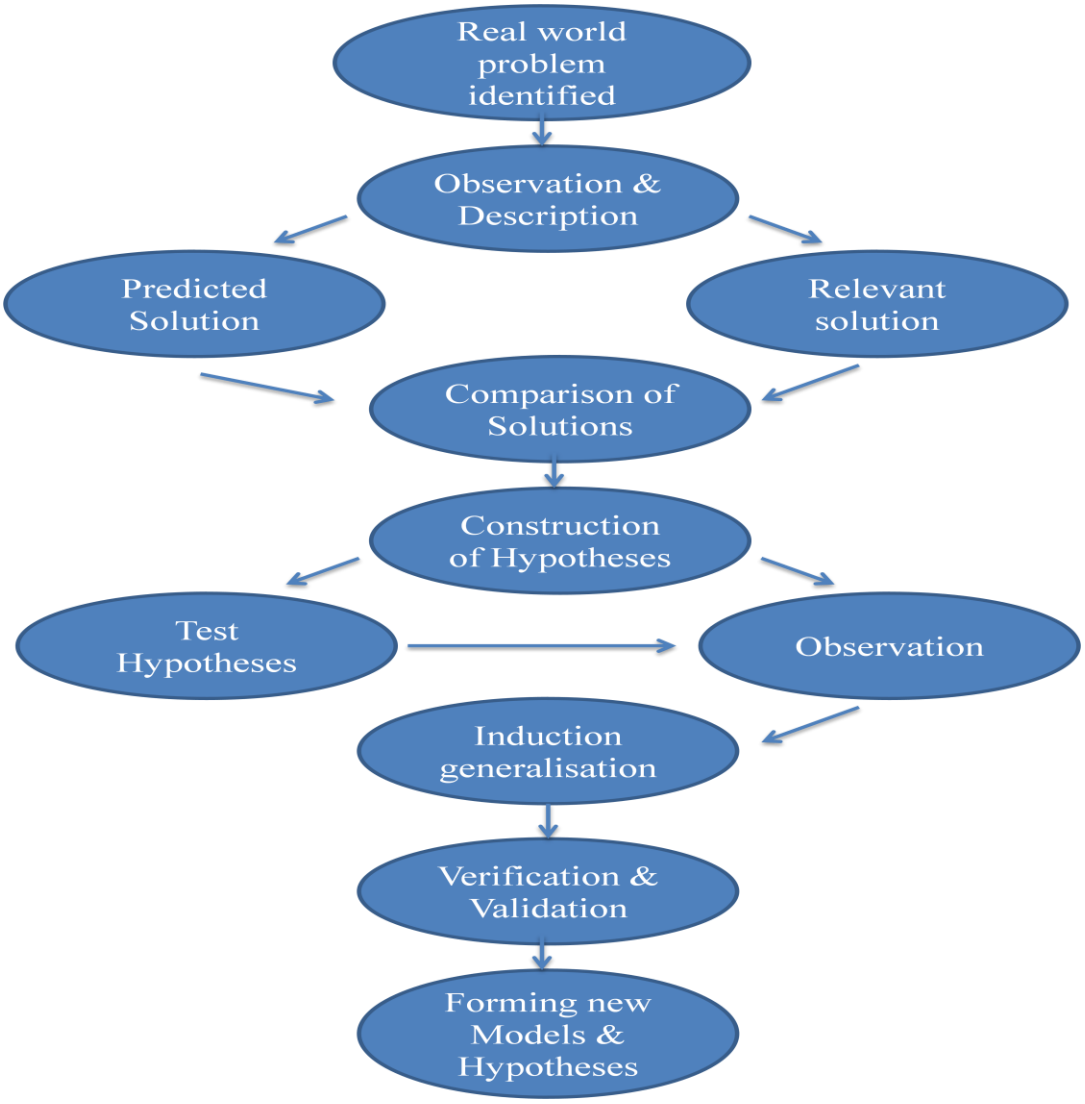
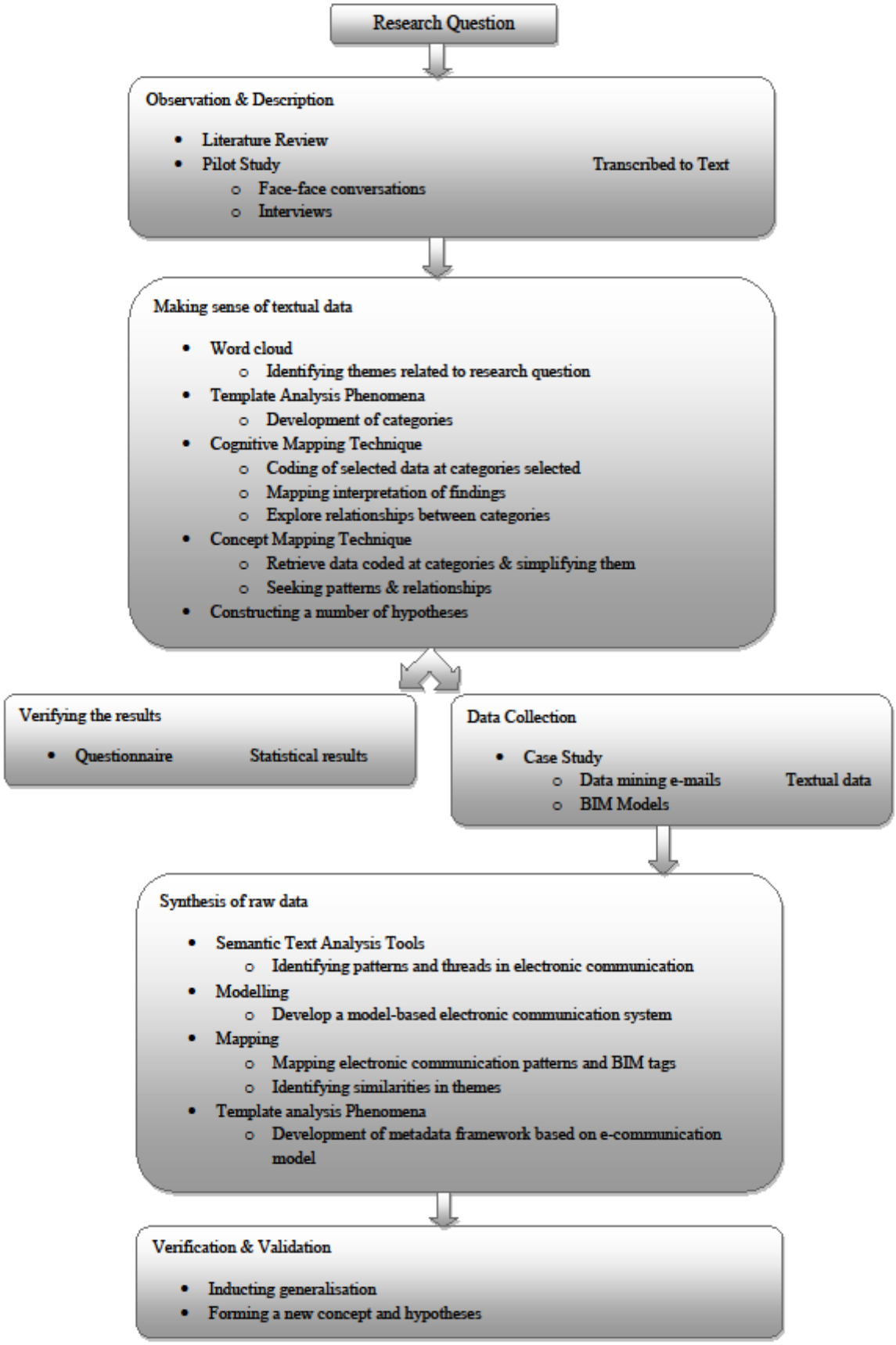
The problem is that people in construction already use too much e-mail for information exchange. They send and recieve

Appendix A – Objectives

What – Objectives	How – Methodology
Create Conceptual and Cognitive maps of existing communication practices to visualise the existing patterns.	Carry out a literature review of art practices in the fields of Electronic Communication, BIM, Computer Mediated Communication, Computer Supported Cooperative Work, Workflow Management Coalition, Organisational Culture and Business Processes will be carried out in the first year of the research to determine those drivers that impact on construction communication. To perform a pilot study, whilst a literature review is carried out, to observe the complexity of current communication patterns across formal and informal working practices; to observe this at an organisational, project and individual level. Literature review and pilot study will enable the researcher to establish a conceptual map of key issues relating to electronic communication platforms, BIM processes and technologies.
Determine the relationship between data mining e-mails and 3D information models.	Work closely with 4projects to identify the ways in which people are communicating currently and monitor the electronic communication patterns on a number of live construction projects on a precise level and create a model of communication based on non BIM users' experience. Also look into BIM models (tags and annotations) to recognize the requirements needed to communicate around a BIM model. This will allow the researcher to determine the relationship between data mining e-mails and 3D information models.
Develop a metadata framework to facilitate the integration between BIM and E-mail.	Based on the communication model, communication patterns and identified relationship between electronic communication and BIM models a metadata framework will be developed using ifcXML industry standard to facilitate a link to connect the unstructured e-mail content to BIM.
Test the developed metadata framework on a number of key BIM users and improve the existing communication workflow processes around BIM models.	A plug in software to Revit Models will be created to extract the necessary data. The piece of software and the metadata framework will be linked to visualise and automate the process of extraction and reformation of information.

Appendix B - Methodologies




Research Question
Observation & Description
Literature Review
Pilot Study
Face-face conversations
Interviews
Transcribed to Text
Making sense of textual data
Word cloud
Identifying themes related to research question
Template Analysis Phenomena
Development of categories
Cognitive Mapping Technique
Coding of selected data at categories selected
Mapping interpretation of findings
Explore relationships between categories
Concept Mapping Technique
Retrieve data coded at categories & simplifying them
Seeking patterns & relationships
Constructing a number of hypotheses
Verifying the results
Questionnaire
Statistical results
Data Collection
Case Study
Data mining e-mails
BIM Models
Textual data
Synthesis of raw data
Semantic Text Analysis Tools
Identifying patterns and threads in electronic communication
Modelling
Develop a model-based electronic communication system
Mapping
Mapping electronic communication patterns and BIM tags
Identifying similarities in themes
Template analysis Phenomena
Development of metadata framework based on e-communication model
Verification & Validation
Inducting generalisation
Forming a new concept and hypotheses

Appendix C – Example of a Cognitive Map

Appendix D – Example of a Concept Map