# EVALUATING AND IDENTIFYING OPTIMAL BIM COMMUNICATION PATTERNS WITHIN DESIGN AND CONSTRUCTION PROJECTS

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The shift from paper based communication to exchange of electronic copies of documents and drawings has made project participants overloaded with information. Electronically exchanged information could be better supported through BIM and automation of routing information using workflow management technologies to improve information availability for decision making. However, it has been observed that BIM is currently being utilized as a number of disconnected models. The built-in intelligence in BIM allows automated updating and extraction of 2D drawings, documentation and other building information. Extracted documents create extra work to be communicated to project teams. Therefore more tasks and communications are created. Accordingly, this study identifies the impacts of BIM in project team communication. It also critically evaluates electronic communication patterns and people's activities by data profiling to identify variables and project characteristics that have an impact on electronic communication level.

Keywords: building information modelling, collaboration, computer mediated communication, computer supported cooperative work, electronic communication

## INTRODUCTION

Architecture, Engineering and Construction (AEC) is a multi-disciplinary and multi-national industry which has an important role to play within UK's overall economy. It is a major contributor to UK Gross Domestic Product (GDP), 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 construction is "one of the most effective sectors", maximum output is expected from it (UKCG, 2009). But according to governmental reports by Latham (1994) and Egan (1998, 2002) and other researchers (ROADCON 2002 & 2003; Constructing Excellence 2003; Akintoye & Main 2007) lack of collaboration and poor quality communication has resulted in increase in cost as well as the instances of defects and has not allowed the industry to generate more benefit in terms of cost and time.

In this context, it is vital to distinguish between collaboration and communication. Indeed, failue to differentiate between the two was observed during data collection. Many times people referred to communication systems as collaboration platforms and vice versa, without realising the fundamental difference between 'collaborating' and 'communicating'. Thus, a clear and distinct definition is made to avoid any confusion. According to Riemer, Steinfield & Vogel (2009) there are different forms of interaction in a group:

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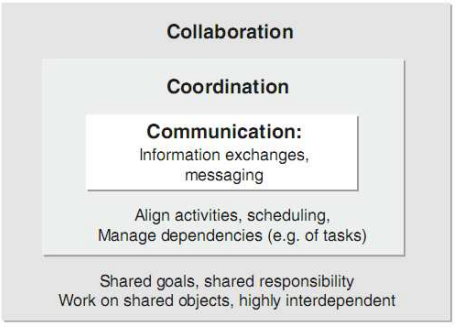


*Figure 1: Forms of interaction in a group (Riemer, Steinfield & Vogel 2009)*

The full meaning of communication is difficult to explain, because there are different types of communication:

- Verbal Communication
- Non-verbal Communication
- Written Communication
- Visual communication

However communication in this study is defined based on written communication. This is because project teams are geographically dispersed (different locations and different times) therefore they mainly communicate via text-based communication systems and evaluation of electronic communication patterns will be carried out based on text-based communication systems. As shown in Figure 1, communication is the core part of collaboration. Communication is the exchange of information between a sender and a receiver through a channel to create a shared understanding. So any communication has a channel and content. In this context, communication channel is a transporter to deliver messages and communication content refers to the available information in a message.

Collaboration on the other hand requires mutual understanding and trust within a team of people working together on shared knowledge to achieve a goal, i.e. complete projects on time. There are tools and processes involved in a collaborative environment for getting work done cooperatively. Therefore communication systems and communication itself are essential tools and processes that are needed in order to share the knowledge between group members.

Effective communication is vital for efficient collaboration and properly functioning of construction projects and failing to communicate will result in low quality and productivity. Inaccuracy and errors in traditional 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, ROADCON 2003). Until recently this problem has been ameliorated through the use of standardised procedures based on traditional working practices. But as technology grows rapidly in construction industry, better use is anticipated to be made of it to improve the working practices and develop more efficient collaborative workflows (ROADCON 2003). Lack of automated integration in construction project teams has been highlighted mainly by ROADCON report (2003). Widespread use of Computer Aided Design (CAD) and increased levels of integration and automation between e-mail and project collaboration tools has provided the motivation for the exchange of 3D data in the same way. The Construction Industry needs solutions to

enhance automation and integration of available collaboration and communication technologies to improve traditional business processes (ROADCON 2003).

The introduction of Building Information Modelling (BIM) and workflow technologies is understood to bring a challenge to established ways of working and improve the traditional processes. BIM delivers a 3D model through which information about all aspects of a construction project can be accessed. Workflow management systems automate the routing of information between project participants. Together these technologies are believed to have the potential to significantly alter existing methods of communication and improve collaboration amongst project teams.

BIM is a consistent technology and an advanced approach to CAD for handling structured data (everything known about the building) in a single and centralized database. BIM applies intelligent relationships between components in the model and enables the visualisation and development of 3D spatial models of buildings and intelligent objects. However, after the first run of data collection it was clear that BIM as a single and centralised database is not currently being utilized in most project teams. BIM is currently being used as a number of disconnected models by stakeholders as 3D visualisation software for document creation (so called 'lonely BIM'). The built-in intelligence in BIM allows automated updating and extraction of 2D drawings, documentation and other building information from the BIM model. Because BIM allows automatic updating, building models get updated automatically every time there is a small change to reflect the changes.

The updating process has resulted in many documents and drawings being created. Since 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. Extracted documents create more work for participants to communicate and distribute amongst the project team. Therefore communication created as a result of the extra work will result in an increase more drawings, documents and files to be communicated and more discussions on information being processed. Based on these findings, it has been hypothesised that: Implementation of separate BIM models and the use of traditional working practices will create more electronic documents to be communicated, as a result: an increase in electronic communication volume.

Thus, the focus of the research is on the current adoption trend of BIM within project teams. The study investigates the existing communication patterns within construction project teams. It identifies the channels and ways in which project participants communicate and distinguishes which communication protocols are important to project groups. The study also critically evaluates electronic communication patterns and people's activities by data profiling to identify and classify variables and project characteristics that have an impact on electronic communication level.

## RESEARCH METHODOLOGY

The researcher's background has been in Computer Sciences, so the Construction Industry is new with many unknowns. Therefore as the study proceeds, the researcher engages in the process of improving prior knowledge through new experiences. This social research has adopted a mixed method strategy; combination of qualitative and quantitative methods (see for example, Bryman, 2008). Data are collected in two

stages; the initial stage is largely exploratory: to observe 'what' is happening and use inductive reasoning to generate a hypothesis and is made of two research techniques; pilot study and focus groups. The second stage of the study is explanatory: to demonstrate 'why' it is happening and using deductive reasoning achieves a clear demonstration and a validation of the hypothesis. Findings from both stages are used to evaluate the electronic communication patterns within construction projects. Findings reported in this paper are based on the following combined research techniques:

- A pilot study to ; a) investigate the existing communication practices, b) instability in project's 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 individual's experiences. This
- 2 focus groups to approach more professionals in industry to confirm the preliminary research data and also to identify project participant's expectation and perceptions of BIM and existing BIM applications.
- Mapping techniques to develop a hypothetical/theoretical model that can be measured.
- Correlation analysis through 4projects SQL database which will be used as a means of establishing a correlation between variables and the level of electronic communication.

**First stage - Qualitative**

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

*Pilot Study*
A 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 individual's experiences at project and organisational level. The pilot study was conducted 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 way in which they communication and exchange information
- Types of communication systems they use to communicate
- The project's quality assurance, contractual agreements and procurement methods
- The project's communication strategy and policy
- Understanding of electronic communication systems, mainly e-mail and how they use them

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. 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

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 transcribed accurately and accordingly. NVivo 8 and word clouds 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.


*Figure 2: Word Cloud*

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

*Table 1: Word Count*

| Order | Unfiltered word count | Occurrences | Percentage |
|---|---|---|---|
| 23 | e-mail | 123 | 0.7145 |
| 34 | people | 124 | 0.4868 |
| 35 | project | 121 | 0.4750 |
| 43 | information | 102 | 0.4004 |
| 105 | communication | 39 | 0.1531 |

Cognitive mapping technique was used to represent individual's knowledge about the five 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). 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.

After completion all the maps were compared to discover relationships and variables that affect the electronic communication systems. The main variables that emerged from the maps and had direct effects on electronic communication were as follow:

- Construction Culture
- People/ Personal Behaviour
- Information Flow/ Information Control/ Information Management
- Roles and Responsibility
- Company QA

- Traditional ways of working
- Procurement Method/ Project type
- Communication methods
- Contractual agreements

After completion of the pilot study, the researcher had gained a better understanding of construction processes and communication patterns. This has led in 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.

*Focus Groups*

Two focus groups were created to identify industry's understanding of BIM, how it is getting implemented, professional's expectation and perceptions of BIM and existing BIM applications. 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 from their diverse sectors. They 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 focus groups were moderated by the Northumbria University BIM Academy research team, who are currently working on a bigger project with these companies. The focus groups were observed and tape recorded and transcribed in a table format, demonstrating the important and relevant points to pilot study and the aim of the research (Table 2). All the important points were linked to the coding scheme previously designed at pilot study stage. Data analysis based on this coding scheme and table allowed the visualisation of various issues and concerns discussed by participants.

*Table 2: Examples of participant's 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 | 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 requirements 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 |

The focus group's findings suggest that implementation and adoption of a single BIM model for interdisciplinary collaboration require an understanding of the collaboration

requirements and project specific contingencies (Singh, Gu & Wang 2011). Findings from this preliminary phase demonstrate that:

- There are different tools to create and maintain building models
- Different modelling tools have different file formats and model representations
- Interoperability and file size issues – ability to share information between different models without the need to extract models as files
- Perception, understanding and expectations of BIM differ across disciplines
- General unfamiliarity with the concept of BIM
- Because information issuing is changing with BIM, authorities and responsibilities must be fully recorded and managed
- Issues relating to model validation
- New roles and responsibilities should emerge, especially for more complex projects, to manage information and BIM models
- Poor discipline integration – need for a new design process; Integrated Project Delivery (IPD)
- Integrated BIM model and IPD needs extra communication and collaboration across disciplines
- Diverse project contractual agreements and internal working practices
- Only a significant number of projects are using BIM during the project life cycle – lack of clarity and guidelines as to how to implement BIM
- BIM is not being used as a single live (social) model – not all stakeholders are familiar with BIM or has adopted BIM
- BIM is being used as a number of disconnected models exclusively designed for multi-disciplinary design teams

Professionals are using BIM as a number of disconnected models ( 'lonely BIM') exclusively designed for multi-disciplinary design teams. Because BIM allows automatic updating, building models get updated automatically every time there is a small change to reflect the changes. Updating process and separate BIM models have resulted in many documents and drawings to be created. Because users are still bound to conventional ways of working (document-based workflow), 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. Extracted documents create more work for participants to communicate and distribute them amongst the project team. Promise of BIM to move towards IPD and have a collaborative workflow has not been achieved with the implementation of separate models and use of traditional working practices.

# DISCUSSION

Even though construction has been revolutionised by development of new technologies and the internet, yet practitioners' approach to available technologies is highly sceptical and there is a reluctance to replace the old 'document-based workflow' with new 'model-based interactions' because they are tightly bound to the traditional contractual agreements and procurement methods in the industry. Discussions from the pilot study suggest that even though project extranets have been developed as a means of online collaboration platforms to share and exchange project information, e-mail has become the main channel of communication and information exchange. This is mainly because; firstly it is expensive for small-medium size firms to employ an extranet site (especially on smaller projects), secondly sending e-mail is

easy, convenient and free. Discussions from the focus groups suggest that lack of knowledge about BIM has resulted in lack of innovation and motivation to adopt a BIM-based communication workflow and collaboration platform. As a result of this lack of innovative drive and confidence to adopt BIM, the level of knowledge about BIM has also remained low. The scope of BIM is to have a single platform through BIM-server for direct integration, automation and exchange of data from various disciplines, nevertheless there is no clear evidence of this being the case in the AEC industry.

According to a study completed by Succar (2009), 'technology', 'process' and 'policy' are the three main fields of BIM implementation. However, results from both pilot study and focus groups indicate that in any communication that occurs around BIM models 'people' and their behaviour and attitude towards understanding and accepting technology as well as communicating the right information is involved too. Because this study has been designed to emphasize understanding of social phenomena within construction projects and also is investigating and evaluating electronic communication patterns from a social scientist's point of view, the researcher believes that the 'people' field plays a significant and vital role for this study. Hence four fields of: 'technology', 'process', 'policy' and 'people' are the main forces that influence communication in construction projects and must be considered when implementing BIM.


*Figure 3: Forces influencing communication*

Findings from the focus groups and variables directly affecting communication in construction projects that emerged from the cognitive maps completed in pilot study can be categorised under the four forces identified.

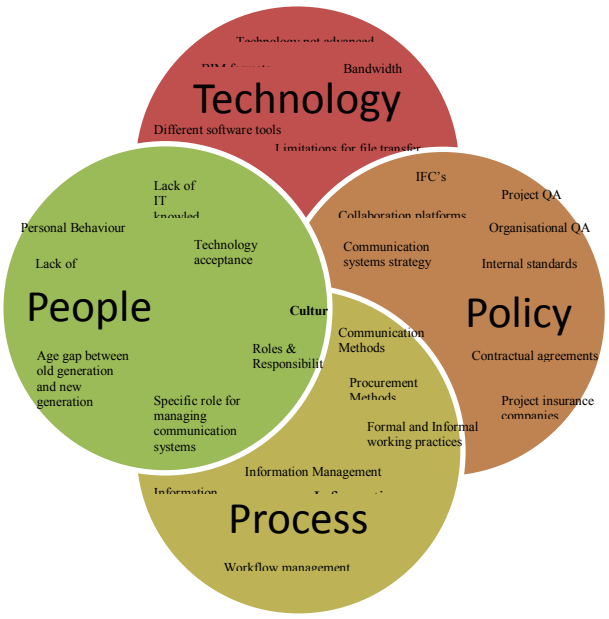

*Figure 4: Classified variables and findings (venn diagram)*

Technology

- BIM can't be used as a single model (BIM server) because technology is not advanced enough due to bandwidth limitations and interoperability issues
- BIM has not been adopted by all stakeholders, mainly because they are resisting to change but also because of lack of knowledge about BIM
- Stakeholders who have adopted BIM are using it as a software tool rather than a centralised repository

People

- People tend to work in a way that they are most comfortable at and use electronic communication systems such as e-mail as a get out of jail system (construction culture)
- People are used to using old systems because they have been round for many years and some like e-mail are free and easy to use
- Massive age gap between old and new generation
- Lack of IT and BIM knowledge - mainly because it costs the organisations to train them
- No specific role or responsibility for document management
- There is poor project management and people are relying on electronic communication and intelligent systems

Processes

- There are two sets of working practices which include two sets of communication practices - formal and informal (construction culture)
- Drawings are still accepted as formal documents because of construction culture and traditional codes of practice

Policy

- BIM server is not currently being utilized due to professionals worrying about liability issues (ownership of models and insurance companies)
- Still employing traditional project procurement methods with no communication strategies
- Lack of guidance (mainly from the government) as to how to get full benefits from implementing BIM

As shown in figure 4, culture is the core and overlapping field of all factors. Culture is an evolving element to any group; it comes from the basic and underlying assumptions and beliefs of its members (Brewer and Gajendran 2011). This also shapes their attitude and often their consequent behaviour towards certain situations (Brewer and Gajendran 2011). In construction, culture is shaped via the four forces and plays a significant part in making the forces a driving movement or a blocking movement towards a more efficient BIM implementation.

# CONCLUSIONS

Communication, collaboration and BIM are the most important and most talked about concepts represented in the field of Information Technology (IT) and Information Systems (IS) in construction. Study of enhanced communication and collaboration in construction is not new. However, 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. Lack of conceptual understanding of communication patterns will limit the knowledge 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 evidence in the industry. As a result this research has adopted a broad approach to the literature to review and comprehends fields of Communication and BIM to analyse the available information with regards to construction project context and with the goals of: a) educating about construction processes, procurement methods, communication practices and project management, b) identifying drivers that have an impact on construction communication (mainly electronic communication), c) seeking similar studies in other fields with the focus on communication problems, d) results from variety of BIM implementations/white papers/case studies to assist an insight into an appropriate evaluation communication framework to be applied to the data analysis in this project. The purpose of this research is to investigate the existing electronic communication patterns to provide comprehensive metrics according to which communication patterns can be evaluated during BIM implementation to better support IPD.

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