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THE VIRTUAL INTERACTIVE RELATIONSHIP BETWEEN BIM PROJECT TEAMS

Effective Communication to aid Collaboration in the Design Process

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Abstract. Building Information Modelling (BIM) provides a shared source of information about a built asset, which creates a collaborative virtual environment for project teams. Literature suggests that to collaborate efficiently, the relationship between the project team is based on sympathy, obligation, trust and rapport. Communication increases in importance when working collaboratively but effective communication can only be achieved when the stakeholders are willing to act, react, listen and share information. Case study research and interviews with Architecture, Engineering and Construction (AEC) industry experts suggest that synchronous face-to-face communication is project teams’ preferred method, allowing teams to socialise and build rapport, accelerating the creation of trust between the stakeholders. However, virtual unified communication platforms are a close second-preferred option for communication between the teams. Effective methods for virtual communication in professional practice, such as virtual collaboration environments (CVE), that build trust and achieve similar spontaneous responses as face-to-face communication, are necessary to face the global challenges and can be achieved with the right people, processes and technology. This research paper investigates current industry methods for virtual communication within BIM projects and explores the suitability of avatar interaction in a
collaborative virtual environment as an alternative to face-to-face communication to enhance collaboration between design teams’ professional practice on a project. Hence, this paper presents comparisons between the effectiveness of these communication methods within construction design teams with results of further experiments conducted to test recommendations for more efficient methods for virtual communication to add value in the workplace between design teams.

**Keywords:** building information modelling, collaborative virtual environments, virtual & augmented reality, professional practice.

1. Introduction

As the Architecture, Engineering and Construction (AEC) industry competes in a global economy Multi Office Execution (MOE) of projects is necessary to achieve quality services at competitive costs. With MOE, there is a requirement for geographically dispersed teams to collaborate and communicate (Larsson, 2003) using virtual communication methods. Effective methods for virtual communication in professional practice, that build trust and achieve similar spontaneous responses as face-to-face communication, are necessary to face the global challenges and can be achieved with the right people, processes and technology.

To understand how effective virtual communication methods are it is necessary to understand the difference between communication and collaboration. The Oxford Dictionary (2015) definition of collaboration is ‘The action of working with someone to produce something’ and communication is ‘the imparting or exchanging of information by speaking, writing, or using some other medium’. The commonality between all definitions of Building Information Modelling (BIM) is that it is a shared source of information about a facility forming a reliable basis for decisions during its life-cycle (Eastman et al, 2012). This shared information is the result of the various project stakeholders input into a single source of data through individuals or organisations working together or collaborating to
address problems and deliver outcomes not effectively achieved by working separately or alone.

According to Ward (2013), collaborating in a BIM environment requires a profound change to project team configuration, project infrastructure along with roles and responsibilities at both inter-organisational and intra-organisational levels. Communication increases in importance when working collaboratively but effective communication can only be achieved when the stakeholders are willing to act, react, listen and share information (Emmott et al, 2013). Ward (2013) also suggests that to collaborate efficiently the relationship between the project team is based on sympathy/obligation, trust and rapport, which he defines as ‘Social Capitol’. This obligation encourages teams to openly share and communicate throughout the design process. The premise of this study is that the current virtual interactive relationship between the project team in the BIM environment does not encourage open communication or information sharing resulting in poor collaboration between the design team members. The research will investigate methods for effective communication to aid collaboration throughout the design process. The investigation will consider what the virtual relationship between the project team is, how the team collaborate/communicate, what are the challenges to virtual communication between the BIM design team players and methods to improve their interaction.

2. Review of Literature

The literature reviewed for this paper considers team collaboration, traditional and virtual communication methods and the types of team players.
2.1. BIM TEAM COLLABORATION

Project Design Team Collaboration is achieved through a coalition of multi-disciplined, multi-skilled individuals with varying values, attitudes and goals to deliver a project (Emmitt et al, 2013). Teams of individuals or organisations working together can address problems and deliver outcomes not effectively achieved by working alone or in silos. Since Building Information Modelling (BIM) is a shared source of information about a building (Ward, 2013) it encourages the design team to collaborate. This alliance between design team stakeholders to work collaboratively is not currently experienced by many organisations adopting BIM. This is likely due to a tradition of fractured adversarial relationships between project teams where a lack of trust between the teams does not encourage open sharing of information to aid collaboration (Macdonald, 2012).

To understand where the roadblocks in this process are, the next section explains the current methods for communication in a BIM project.

2.2. COMMUNICATION

Traditionally design teams have used Computer Aided Design (CAD) technology to automate hand drafting (Kouider et al, 2007) using traditional communication methods to collaborate throughout the project. The adoption of BIM has advanced this process to provide a new method of communicating digital documentation about a building, its performance, planning, construction and operation (Eastman et al, 2012).

Stempfle et al. (2002) proposed that communication allows for the thinking and problem-solving process of the design team through two methods, synchronous and asynchronous. Synchronous communication is when individuals or groups such as design teams communicate face to face through interactive dialogue by telephone, in meetings or with video conferencing. This method is cited as being essential for problem-solving, developing trust and exploring values amongst the design team stakeholders (Emmitt et al, 2013). Asynchronous is a communication method where the interaction between parties is not instant or where they
do not interface concurrently; correspondence media include mail, text messaging, post etc. Since synchronous communication is not always possible due to working hours, design team locations etc., additional methods of communication are required. Asynchronous communication is used when an instant response is not necessary or when the respondent is required to assimilate information before responding (Emmitt et al, 2013).

<table>
<thead>
<tr>
<th>Location</th>
<th>Synchronous (Same Time)</th>
<th>Asynchronous (Different Time)</th>
</tr>
</thead>
</table>
| Same Place Co-located | Face-to-face Interactions  
Meetings, Shared table, over the shoulder discussion | Continuous Task  
Team Rooms, Public displays, Shiftwork |
| Different Place Remote | Remote Interactions  
Videoconferencing, instant messaging, shared screens,  
Unified Communications System, dynamically linked models | Communication & Coordinate  
Email, information issues/ model sharing (data drop), Document Management Systems |

2.3. VIRTUAL COMMUNICATION

Synchronous communication or meeting face to face is an effective way to interact with the design team, to make decisions and agree actions but in this evolving industry, this is not always possible with the design team working in difference locations and often in different countries. One way for the design team to meet and communicate is virtually or to communicate from remote locations using information technology methods such as instant messaging (IM), videoconference, computer screen sharing etc. According to Leenders et al. (2003), communication technology is more effective when it is used to supplement rather than replace face-to-face interaction since this does not provide the same spontaneous interaction between the team that face-to-face can. Science Fiction and the
film industry have been depicting virtual environments where people can plug in and interact with each other virtually (The Matrix, 1999). The people in these environments take on humanoid features and synchronously communicate with each other (Avatar, 2009). This type of environment and humanlike interaction is not solely used in science fiction; a collaborative virtual environment (CVE) enables groups of people to collaborate and communicate together in a virtual environment (Schroeder et al, 2006). This is achieved through avatars, graphical representations of human characters, that converse with each other in a CVE or a virtual world such as Second Life or Open SIM (Ward, 2015). CVE’s were first used in the 1980’s for military simulations such as pilot and combat training (Pečiva, 2007).

The computer gaming industry has been using avatars as first person representations since Maze War in 1973 and more recently with massively multiplayer online role-playing games (MMORPG). World of Warcraft, one of the most popular MMORPG’s (Tassi, 2014) in recent years, allows the players to select and customise a character (avatar) to work collaboratively with other characters in guilds (teams) to complete tasks and defeat opponents. This collaborative working is supported by internal chat systems where the players can communicate through private chat (players can chat privately with each other) or guild chat where they can communicate as a group. Gamers also utilise communications systems or Voice over IP (VoIP) software to communicate with other gamers online. Technology advancements such as brain-computer interfaces will make this interaction more spontaneous. This is in addition to the presence of immersion using Virtual Reality, superimposition of virtual objects in real environments using Augmented Reality and Mixed reality using a combination of both (Cohen et al., 2015).

2.4. DIGITAL NATIVES AND IMMIGRANTS

A barrier to interactive communication and open collaboration with Building Information Modelling (BIM) projects may be the lack of
engagement by the design team with the tools and processes. For the design
team to interrogate and interact with a project’s digital information they
must be familiar with the digital tools such as BIM authoring software,
review software etc. Yet design teams can comprise of different dynamics,
work cultures and levels of experience (Levi, 2016). The senior team
members could be more mature and experienced; the less experienced team
members could be less mature, newly graduated, however, more technically
savvy. This dynamic may have an impact on how the team engages with
the digital tools in a BIM project. The junior team members’ generation has
grown up in a digital era using mobile phones, computers etc. as an integral
part of their life and are known as Digital Natives. According to Prensky
(2001) they prefer graphics to text and expect to receive/exchange
information rapidly. Digital Natives are suited to BIM process, which
entails handling project information contained in a virtual environment
accessed at any time as a graphic representation of the building. The
opposite of this may be said of the more mature team member who has not
grown up immersed in digital technology. Prensky (2001) describes them
as Digital Immigrants who learnt a new language to engage and
communicate with Digital Natives and their technology. The mature team
members may feel uncomfortable with new technologies as described by
Kouider et al. (2007), and as Prensky (2001) notes they retain habits from a
non-digital past such as printing documents to read rather than reading on
screen, requesting prints of drawings to review rather than utilising digital
review tools etc. To encourage interactive communication and open
collaboration with BIM projects the team needs to engage virtually rather
than in a traditional synchronous or asynchronous form, which involves
changing a mindset for the digital immigrants.
3. Research Rationale and Description

The objective of the research was to explore the following:

- The current virtual relationship between the BIM design team
- The difference between collaboration and communication
- The challenges to virtual communication between a BIM team
- Project team interaction between different generations (digital natives and immigrants)
- Alternative more efficient methods of virtual communication can add value in the workplace between design teams

This was carried out with case study data collection through observation and semi-structured interviews with project teams along with industry expert interviews and finally experimentation of a proposed solution.

3.1. CASE STUDY

A Qualitative Case study research methodology was employed to investigate the current interaction and communication methods used by a project team during the design process of a live construction project, which was procured using BIM processes. This particular case study was selected for research as it involved a multi-disciplinary team co-located in three geographic locations where the team members interacted and communicated virtually throughout the project lifecycle. Team meetings were observed and project artefacts such as action lists were collected to study the effectiveness of the team interaction. Figure 1 is an example of a clash resolution meeting observed by the author, which was carried out virtually with a unified communication (UC) platform with Voice over IP (VoIP) and desktop sharing.
3.2. SEMI-STRUCTURED INTERVIEWS

Thirteen (13) individual in-depth qualitative interviews were used for the case study research to collect data from the live BIM Project. The interviews were carried out with a selection of team members from different disciplines (as per Figure 2) in each of the co-located offices and were either face-to-face or via VoIP.

Also, four (4) semi-structured interviews were carried out with a purposive sample of industry experts from the architecture, engineering and construction (AEC) sector to collect data on current industry experience of virtual communication with Building Information Modelling projects. These interviews also sought the respondent’s opinion on virtual interactive
solutions for BIM projects. The interviews were carried out via VoIP and the interviewer took notes and recorded the audio for later data analysis.

3.3. EXPERIMENTS

The purpose of the experiments was to test the premise that more efficient methods for virtual communication can add value in the workplace between design teams. There were eight (8) experiment participants comprising of digital natives and immigrants from the case study project team. Two experiments were carried out in the work environment of one of the case study project offices at the same time over two days. The first was the control experiment where a face-to-face meeting communication method was used to carry out a series of design coordination review tasks. The second used a Collaborative Virtual Environment (CVE) solution to carry out the same series of tasks.

Hence, the only variable altered between the two experiments was the method of communication; face-to-face versus CVE avatars and medium. The same defined tasks were carried out for a particular area of the case study project and a federated review model was interrogated in both scenarios. An example of one of these tasks was the coordination of a congested ceiling void with multiple services (Figure 3).

![Figure 3. Images of Physical Control (Left) and Virtual (Right) Experiments](image-url)
The following software tools were used to carry out the experiments:

- **Review Model**: A review model compiled from exports from the BIM authoring software federated in Autodesk Navisworks was used from the Case Study project. Navisworks Freedom was used to review the model. All the participants were experienced Navisworks users not requiring additional training.

- **Collaborative Virtual Environment (CVE)**: AvayaLive Engage is the virtual reality immersive collaboration space used. The participants communicated and interacted using personalized avatars within a customized pre-prepared virtual meeting room using audio and screen sharing. Training was provided in advance as none of the volunteers had experience using a CVE prior to the experiment.

An evaluation questionnaire was completed by each participant to compare the control and the virtual environments under the following topics:

- Project Team Collaboration on BIM projects
- Project Team Communication on BIM projects
- BIM Collaboration and Communication
- Digital Natives and Immigrants
- Collaborative Virtual Environment

### 4. Discussion of Results

The results discussed below are based on qualitative data collected from the semi-structured interviews with team members from the case study project and purposive industry experts along with quantitative data collected from experiment evaluations.
TABLE 2. Number of Respondents

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case Study Interviews</td>
<td>13</td>
</tr>
<tr>
<td>Purposive Interviews</td>
<td>4</td>
</tr>
<tr>
<td>Experiments</td>
<td>8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>25</strong></td>
</tr>
</tbody>
</table>

4.1. DIFFERENCE BETWEEN COLLABORATION AND COMMUNICATION

The respondents were asked a series of questions to determine their understanding of collaboration and communication in a BIM project context. Regarding team collaboration, 14 out of 17 of both the case study and purposive interview respondents described it as working together, while only 3 referred to it as delivering or achieving a common goal. Communication was described by 12 out of 17 of the interviewees as a method to exchange information while 5 interviewees defined it as a method of collaboration. Results show indecisiveness and non-clarity in defining differences between collaboration and communication, hence indicating possible ineffectiveness in choosing the best methods to enhance them due to the vagueness of objectives for each term.

4.2. VIRTUAL RELATIONSHIP / CHALLENGES BETWEEN THE BIM TEAM

The data collected from both the case study and purposive interviews determined that the three main methods of virtual communication currently being used, often in tandem, in the construction industry are Unified Communication systems (Microsoft Lync / GoToMeeting – used by 11 out of 17 interviewees), BIM (Navisworks/ Revit Server used by 10 interviewees) and Email (used by only 3 interviewees).

When asked to discuss BIM team collaboration and virtual interaction 12 out of 17 of both the case study and the purposive respondents agreed
THE VIRTUAL INTERACTIVE RELATIONSHIP BETWEEN BIM PROJECT TEAMS

that they experienced better collaboration, 5 respondents agreed that there was better coordination between disciplines and more understanding of the project. The cons experienced by the two groups of respondents were that more time was required as more coordination was possible with the virtual environment.

Regarding challenges, 11 of 13 of the case study and 3 of 4 of purposive respondents noted that virtual communication is not as effective as face-to-face communication, as body language cannot be used to aid communication. This is a challenge to current virtual communication tools as Mehrabian’s (1981) 7%-38%-55% Rule explains that only 7% of communication is verbal with 38% being tone and 55% being gesture. Therefore, the respondents’ view is that 55% of the communication between the team is being lost through virtual communication methods. Technology problems such as slow Internet connections or problems sharing data were identified as challenges to virtual communication by the case study interviewees.

4.3. PROJECT TEAM INTERACTION BETWEEN DIFFERENT GENERATIONS (DIGITAL NATIVES AND IMMIGRANTS)

The interviewee dynamics for both the case study and purposive interviews were mostly digital immigrants (Table 3). This may be a reflection of typical project team dynamics where the more experienced team members such as discipline leads and project managers are older digital immigrants. This may also be said of the purposive group who by their selection for interview are experts with industry experience from BIM projects.

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Digital Natives</th>
<th>Digital Immigrants</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case Study Interviews</td>
<td>3</td>
<td>10</td>
<td>13</td>
</tr>
<tr>
<td>Purposive Interviews</td>
<td>0</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>
The dynamics had an influence on some of the respondent’s answers to interview questions. This is most obvious in the responses to questions regarding the effectiveness of Virtual Communication and Collaborative Virtual Environments (CVE’s). The digital natives thought that a CVE built the same trust between the team as a face-to-face meeting, whereas 11 out of 13 digital immigrants believed face-to-face communication is required to build trust between the BIM team. In contrast to the above views by the respondents, 15 out of 17 of both digital immigrants and natives believed that a CVE will improve communication and engagement between the team and is as effective as face-to-face communication in agreeing better design solutions for coordination, clash resolution and discipline interfaces. These results would suggest that a CVE may have the potential to be a suitable solution for effective communication to aid collaboration throughout the design process. Further investigation through experiments of the CVE solution with avatars is discussed in the next section.

4.3. MORE EFFICIENT METHODS FOR VIRTUAL COMMUNICATION CAN ADD VALUE IN THE WORKPLACE BETWEEN DESIGN TEAMS

Results from the experiment respondents (Table 4 - using both real-life and the AvayaLive environments) demonstrate opinions similar to the interview results showing appetite for more effective virtual communication methods; 4 out of 6 of the digital immigrants disagreed that the Virtual Environment aided the collaboration process and strongly agreed that the control environment aided it, whilst the remaining 2 immigrants and the 2 digital natives believed the virtual environment aided collaboration. When asked if the virtual environment built trust between the team, 50% of all respondents agreed it built trust in comparison to 50% who strongly agreed that the control environment built trust. Digital natives gave higher impact weighting for the CVE on both collaboration and trust.
TABLE 4. Number of Digital Native and Immigrant Experiment Respondents

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Digital Natives</th>
<th>Digital Immigrants</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment Respondents</td>
<td>2</td>
<td>6</td>
<td>8</td>
</tr>
</tbody>
</table>

5. Conclusion

Comparisons between the analysed data collected from three main sources (case study observations and interviews, purposive interviews with industry experts and field experiments) were triangulated. This provided initial direction on the current virtual relationship between the BIM design teams. The data collected also provided a sample of the AEC industries understanding of the difference between collaboration and communication along with the challenges to virtual communication such as technology issues and non-visual communication. Data was also collected from the interviewees and experiment volunteers to determine whether they were digital natives or immigrants. Comparing the results theorised how each demographic responded to different communication/collaboration methods. The field experiments tested whether a virtual environment with avatars for interaction could result in better communication and collaboration through an improved virtual communication environment. Findings from the evaluations showed a discrepancy between opinions of the more senior members of the team (digital immigrants) as opposed to the younger members (digital natives) who favoured Collaborative Virtual Environments (CVE’s) for collaboration and trust. There were various reasons for the unfavourable results cited by the digital immigrants such as the technology was not responsive enough or it was difficult to view a model on a screen in the virtual environment, or lack of experience in the medium. However, the respondents supported this type of technology for future use for being closer to replicating face-to-face interaction then
current virtual solutions. Further research into CVE’s is necessary to resolve the issues cited by the respondents with the goal of having a virtual site meeting in a Building Information Model with avatars of the team members walking down the site and interacting spontaneously to resolve the building design before it is built.

6. References


THE VIRTUAL INTERACTIVE RELATIONSHIP BETWEEN BIM PROJECT TEAMS


