Challenges of Migrating from Desktop-based BIM in Construction

Samad M.E. Sepasgozar[1], Aaron Costin[2], Cynthia (Changxin) Wang[1]
[1] Faculty of the Built Environment, University of New South Wales Australia
[2] Georgia Institute of Technology, USA
E-mail: samad.sepasgozar@gmail.com, aaron.costin@gatech.edu, cynthia.wang@unsw.edu.au

Abstract –

Recent studies increasingly offer new Building Information Modelling (BIM) solutions and some other studies are modelling BIM adoption and implementation practices. However, the migrating process from the current practice of using desktop-based BIM to a web-based BIM covering broader activities of the entire project lifecycle is complicated. This paper intends to develop the migrating process including main factors that inhibit higher level of web-based BIM usage (e.g. digital autonomous online systems) at construction companies. A case study approach is utilised to collect rich data from three contractors that provided best practices of using BIM in Sydney, Australia. The result of the study shows that there are 'challenges' that hinder pragmatists to migrate from lower level BIM usage to higher level BIM implementation at the construction companies. The key challenges of higher level of BIM usage from contractors' point of view can be divided to technical and managerial challenges. Technical factors include availability of internet infrastructure for web-based BIM and compatibility with other available technologies. Managerial challenges include possibility of changing engineering procedure within contractor's organisation and availability of expert and low skill workers. The study contributes in the body of knowledge by deepening understanding of challenges of BIM implementation for conservatives, which may follow pragmatists in adopting more advanced technologies. The results of the study help the industry policy makers who encourage contractors to use higher level of BIM by resolving the challenges and provide more supportive resources or infrastructure for contractors to cope the challenges. The study will expand to investigate more contractors and other AEC companies to continue to uncover more in-depth challenges. Future recommendations include comparing both the levels and types of challenges faced in different countries. The result can be generalised if many other cases investigated across the country. The study will be extended by focusing on infrastructure projects using more interviews, and developing a roadmap to facilitate the target in each country for web-based BIM implementation.

Keywords –

Desktop-based BIM; web-based BIM; Implementation; Process.

1 Introduction

There is a growing desire to introduce new digital technologies to the construction market. There has been also a vast amount of research on introducing such technologies or dealing with the positive impact of technology in construction [e.g. 1, 2-8]. The concern of innovators and vendors is to increase the rate of up take of the technologies, because the awareness of technologies will not ensure that technology adoption will occur [9]. In the architecture, engineering, and construction (AEC) industry, there has been a paradigm shift to convert all construction documentation into digital representations, including the process of designing, constructing, and operating a facility, known as Building Information Modelling (BIM). Australian government suggests compulsory BIM use for public sector projects. BIM is a digital representation of physical and functional characteristics of a facility, and is a shared knowledge resource for information about that facility forming a reliable basis for decisions from early development to demolition [10]. Being a centralized database of information, BIM has many capabilities and degrees of usage, e.g. 2D drawings, 3D model, material information, analysis model, etc. Since there is confusion of how BIM is used, and to what degree, standardized levels need to be established. Therefore, Bew and Richards [11] developed the BIM Maturity Model consists of three levels (0 to 3). Level 0 is unmanaged CAD probably 2D, with paper (or electronic paper). Level 1 is managed CAD in 2D or 3D format using BS1192:2007 with a collaboration tool providing a common data environment. Level 2 is a "Managed 3D environment held in separate discipline 'BIM' tools with attached data. The approach may utilize 4D program data and 5D cost elements as well as feed operational systems" [11]. Level 3 is defined as "Fully open process and data integration enabled by web services compliant with emerging IFC/IFD standards, managed by a collaborative model server. Could be regarded as iBIM or integrated BIM potentially employing concurrent engineering processes" [11]. The hypothesis is that as the usage of BIM increases, the challenges increase as well (i.e. there is a correlation of increased challenges with increased usage). Therefore, this paper investigates the challenges of implementing level 2 and higher level of BIM usage in construction projects.

It has been identified that BIM has been used for many different purposes such as: designing a 3D model [12], safety [13], co-ordination of models (including clash detection and spatial analysis), real-time construction resource tracking [14], and using BIM for FM/operations [15, 16]. Eadie [17] examines the awareness of the current status of the BIM adoption in the UK. The author concludes that current BIM usage within the UK construction sector revolving around development of 3D models and coordination for clash detection. The study concludes that only a few companies surveyed in their sample has used BIM on all of their projects. However, the question that is raised is 'why other companies do not use full potential of BIM when it is known as a beneficial modelling tool?' The process of the migrating from the current practice to higher level of BIM usage for construction purposes (e.g. including key activities, challenges, and influential factors) have been given less attention in previous research. Eadie [17] suggests that future study should argue the increase in the level of BIM implementation to ensure the UK government will achieve its target.

This paper aims to explore challenges of utilizing higher levels BIM usage in construction projects. The main objectives of this paper are: 1) to understand the current practice of contractors; 2) to understand the main challenges of implementing higher level of BIM usage; and 3) to identify the role/importance of a benchmark using high levels of BIM for mid-sized contractors. This paper will focus on the process of implementation and factors hindering the process.

The originality of this paper lies in investigation of contractors view who are experienced with lower level of BIM implementation compared with government desired level of implementation [18]. This is a step forward to conceptualize a framework for the adoption of high level BIM by contractors, who are identified as the most important players in the adoption process. The presented challenges enable policy makers to facilitate wide spread diffusion of full BIM in the construction industry. In addition, the current practice of the BIM implementation and the designed BIM implementation is compared, which would be useful for the next step of the study for developing high level BIM adoption road map.

The paper firstly reviews existing models of technology adoption and implementation and identifies gaps and barriers to the adoption process. Secondly, the research method that includes an in-depth data collection process from a case study using semi-structure interviews' process is explained. Finally, the result of the implementation challenges is discussed and a novel framework of web-based implementation process is presented.

2 Technology Implementation Process

This section reviews the implementation concepts, general models, and provides a structure for further research. The literature in the area of innovation adoption can be classified into three key perspectives: socio-economic perspective [19]; managerial perspective [20]; and psychological perspective [21, 22]. Studies that take a socio-economic perspective have focused on profiling the users of particular technologies in different disciplines. Rogers [19] envisions technology adoption as occurring within a social system where potential technology adopters communicate with each other and make decisions based on a variety of attitudes towards technology. The formative model includes five categories of adopters, namely: 1) innovators; 2) early adopters; 3) early majority adopters; 4) late majority adopters; and 5) laggards [19]. The key premise of this theory is that it conceptualizes innovation relative to individual action, social relationships, and communication. Studies from the managerial perspective focus on innovation adoption in organizations [23]. Finally, studies using a psychological perspective, focus to a series of mental and behavioral states that a person passes through leading to the adoption or rejection of an innovation [24].

The general framework consists of three overall phases that a potential decision maker may pass through: "pre-adoption", "adoption decision", and "post-adoption"

[7, 20, 23, 25-29]. Although the model is general, and does not refer to any clear activity, it still is helpful as the basis of new relevant research to people involving in any phase of the process.

Technology adoption has been studied in many different areas, and has been defined from various perspectives. Costin, Felkl [30] identify an “innovation gap” between academic research technology and industry adoption, and outlines a roadmap to commercialize university research, e.g. safety technology utilizing BIM. According to Rogers [31], adoption is defined as the steps taken in the process through which the adopter passes to reach a decision to accept or reject a new technology. Implementation has different meanings when viewed from different perspectives. For example, from the diffusion perspective IT implementation defines as “organizational effort directed toward diffusion of appropriate information technology within a user community” [32].

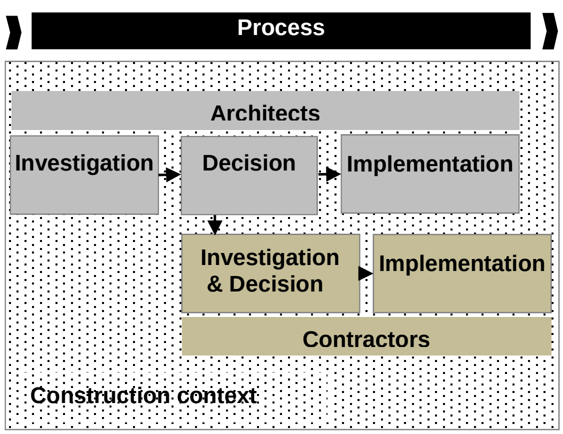


Figure 1 General framework for BIM Implementation

Figure 1 presents a framework for technology implementation process based on previous studies. The framework is an extension of the three overall phases that a potential decision maker may pass through: “pre-adoption”, “adoption decision”, and “post-adoption” [20, 28, 31]. The general process of pre- and post-adoption is modified by considering consultants (architects) and contractors. It is assumed that consultant implements BIM in three main phases: investigation, adoption decision and implementation. Lately, based on their tendering documentation, contractors are highly encouraged to use BIM in a specific project. Thus, the framework is used to structure the overall research approach.

The literature reveals that the adoption and implementation process is complex and not clearly defined in construction [4, 33]. The complexity originates from the lack of uniformity of decision makers, complexity of new projects, and the variety of differentiated activities involved in any construction project [34, 35]. These coupled with the uniqueness of the construction products [36], the nature of the industry itself [37], project-based organisations and the locations [4, 38] produce a growing number of outsourced project participants [39]. This study considers that the construction industry may affect the adoption process, and so investigate challenges of BIM implementation.

Even with the use of various BIM tools, the exchange between non-interoperable software will require manual data entry to an extent. This lack of interoperability creates impediments for the efficient and seamless transfer of information across a facility’s lifecycle. In 2002, Gallaher, O'Connor [40] revealed that the operation and maintenance personnel spent an estimated $4.8 billion (USD) in verifying that documentation accurately represented existing conditions and another $613 million (USD) transferring paper based information into useful electronic format.

3 Research Method

In order to explore the challenges of migrating from desktop-based BIM to a web-based BIM, the case study approach including in-depth interview with the BIM implementer of a construction project has been employed. This method utilized because of its flexibility in obtaining deep understanding of the relative process and influential factors [41]. Qualitative methods were chosen rather than quantitative methods because the literature shows that research is scarce in this area, and so there is a need to investigate and interpret the basic processes occurring, the aim being to produce new insights and understanding of the phenomena concerned [42-46]. Qualitative study is known as a useful research approach to determine richer information about technology adoption [47, 48]. This research strategy enables description of the adoption process, and production of new insight [44].

The semi-structured interview technique was chosen as the best tool to collect data about the vendors and customers’ experiences of the technology adoption process, because it enables the researcher to get in-depth data about the process being studied [41, 42, 44, 46]. This type of interview is a flexible tool that allows the researcher to generate rich data to advance understanding and consequently develop empirically and theoretically grounded argument about the process [41, 46]. By interviewing the implementer managers, we can portrait their perspectives into a larger picture and recognize commonalities [45]. The format of semi-structured interview has been applied in many research studies in construction to investigate a process and the associated related factors such as Agapiou [49], Sarshar and Isikdag [50], Bassioni, Price [51] and Samuelson and Björk [52]. For example, Samuelson and Björk [52] investigate factors that affect the decisions to implement different techniques of information technology in construction as well as the actual adoption process. The authors [36] justify their choice of semi-structured interviews because it allows a wider discussion, while the interview is held around defined areas and the selected theoretical framework. A semi-structured interview is a tool to collect rich data, which are open to the participants' decisions about what is important and relevant to discuss. The case company used a middle size construction company that can be fairly a benchmark for other same size construction companies. The case study has been used from one of the University of New South Wales (UNSW) construction contractors of education buildings. The company has been used were carefully choose their contractors from the available construction companies with good track records of quality and safety, because they are working at the university environment surrounded with a large number of students and staff.

At this stage of the study, in order to develop the implementation framework, a BIM implementer of a project was interviewed from a chosen case study. A total number of four case studies and eight interviewees have been planned, which will be conducted in the next phase of the study. We analyzed the data collected from the case study and the interviewee including transcriptions, sketches and the company procedure using thematic analysis technique, as reflected in grounded theory methods [53].

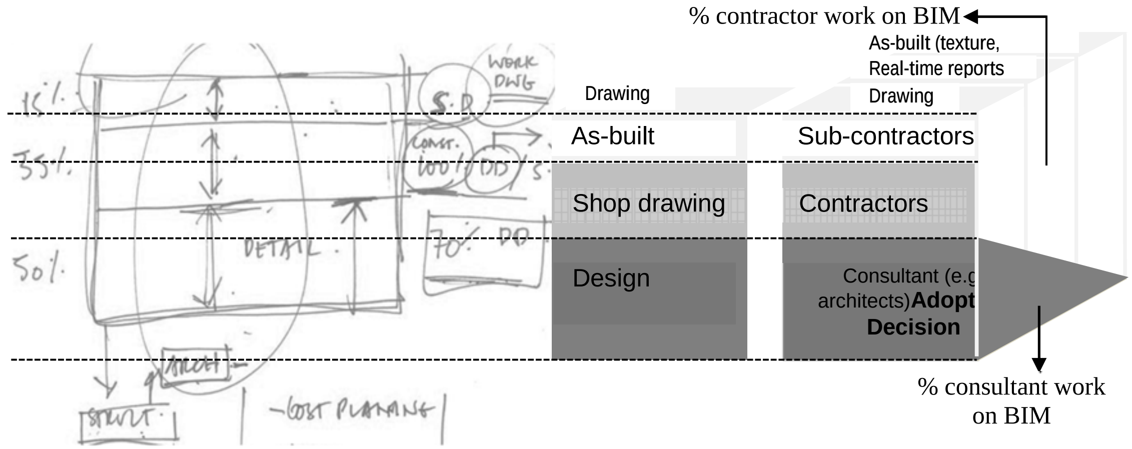
4 Current BIM Practice And Drivers

This section presents the current usage level of BIM in the case study, and compares the current practices of the BIM implementation with the desired level of usage according the literature. Figure 2 shows an example contractor's view from the case study, current practice of BIM usage, and a model of desired BIM usage encouraged by governments and policy makers. Figure 2a shows the interviewees' sketch explaining that 50% of drawings and BIM information will be provided by consultant. The interview shows that the consultant has the main role in decision making to adopt BIM, and contractors had to use BIM as they are committed to in the tendering process. In documented design contracts (DD), consultant provides 70% of information using in BIM. This shows that a contractor has less effort to collect information to use in BIM, even while construction has many different activities occurring on construction sites. The activities, installed materials, and their information are very crucial in the future life cycle of the building, e.g. operations and maintenance [16, 30]. Figure 2b model the current practice of BIM usage in construction based on the case study in Australia. The model is in line with the results of Eadie, Browne [17] study, which show design and build and modeling are the only and most common BIM procurement routes in the UK construction industry. Figure 2c shows the model of desired practice based on the government visions such as the UK [17], Singapore and Australia.

Figure 2 shows there is a clear gap between the current practice of BIM and the desired model for high BIM usage in construction projects. Many associations, champions, and subsequently governments around the world encourage different players in the construction industry to highly use BIM. However, there are still many challenges in using BIM for different purposes other than drawings in construction projects. The challenges are discussed in the next section.

5 Challenges Of BIM Implementation

This section discusses the challenges of migrating from desktop-based to web-based BIM derived from the case study. Then the findings are compared with the existing literature and an overall framework provided for a future study. Figure 3 shows the chasm between early adopters and early majority groups. Chasm refers to differences that exist between innovators and pragmatists in adopting new technologies. The result shows that there should be a large 'challenge' between pragmatists and conservatives in construction. Pragmatists are those companies who are looking for different ways to exploit BIM in order to improve their productivity and situations. Conservatives mostly believe in their traditional way of producing drawings such as deploying AutoCAD for producing 2D documentations. The difference of BIM and any other information systems is that followers (other construction companies such as smaller ones) would not adopt BIM, because early adopters already adopted BIM [54]. The reason is that conservative companies should change some procedures in their company when they are going to use BIM. In addition, the company capability sometimes is not enough to adopt BIM. Therefore, there is a gap between pragmatists who look for new solutions of BIM, and conservative who believe traditional way of drawings are adequate.



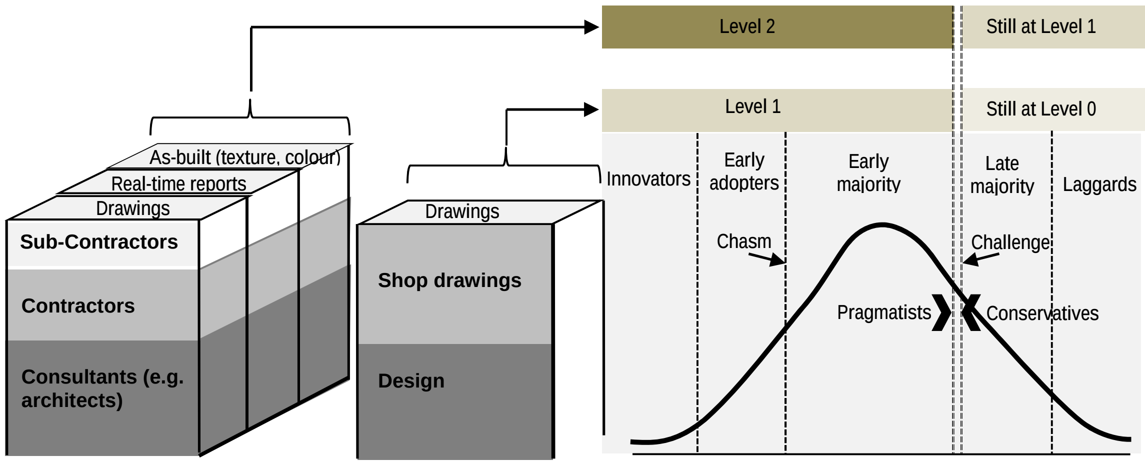
a) Contractor’s view (case study example) b) Current practice c) Desired model

Figure 2 Model high level of BIM usage by contractors.

Figure 3 shows two waves of BIM implementation. The interview shows that a mid-sized company in Australia implemented level 1 BIM in the case project. The main driver for adopting BIM for the company was that the architect company uses BIM. The study explained that they are far from Level two. The challenges will be discussed below. The existing of challenges keeps conservatives away from BIM, although they use 2D CAD and other software for drawing (which can be considered as level 0 of BIM). Therefore, innovators and pragmatists use level 1 BIM and others use level 0 BIM. This pattern is shown as Wave 1. The interviewee explains that their company, which is one of early majority companies, tries to improve their situation and productivity. Therefore, they need higher level of BIM, where governments also encouraged them to move up another level of BIM implementation. This can be called Wave 2 in adoption and implementing BIM in construction. So, a new trend should be defined in the literature about new topics and researchers. This study focuses on Wave 2 and identifies challenges. The second wave refers to the high usage of BIM lifecycle.

The study reveals challenges in adopting higher level of BIM implementation. Key challenges are listed as:

- Project scale – projects with smaller scale of budget and size would not allow us to use higher level of BIM;
- Reluctant to record all information – personal are reluctant to measure and record every activity in the site because of privacy, disclosing data in case of fatality;
- Less skilled personal – the level of personal education and skill is not enough for involving BIM, when higher level of implementation is required;
- Full time experts – there are few (if any) full time BIM experts/technicians in many residential projects;
- Resistance to change – conservative contractors would not happy to change the traditional methods and shift to higher level of BIM, which required changes their current procedures and develop new operation procedures in site;
- Massive information – the amount of information is massive in projects, and contractors cannot collect them automatically in digital format, store them and effectively use them;
- Compatibility – the compatibility of new tools and software with each other is a big concern, which are required for collect data and use them;
- Technical support system – lack of availability of supportive system cause delay in construction project, where everything should occur quickly;
- Lack of bench mark projects – contractors need to have benchmarks of BIM implementation to follow them;
- Budget- Some contractors have a small budget to adopt multiple BIM tools, especially since many are not proven to be cost effective.
- Liability issues- Contracts still require 2D print outs for liability. The use of 3D modelling is still not fully supported by owners;
- Interoperability- Software applications that cannot exchange information present an impediment to adopt various software tools.



c) Level 2   b) Level 1   a) BIM diffusion life cycle

Figure 3 Two waves of BIM implementation life cycle at two levels.

6 Conclusion

This paper was aimed 1) to understand the current practice of contractors; 2) to understand the main challenges of implementing higher level of BIM usage; and 3) to identify the role/importance of a benchmark using high levels of BIM for mid-sized contractors. The case study approach was used in order to understand the current practice of contractors in Australia, and identify key challenges of BIM implementation in their organization.

The result of the study reveals that consultant provides the main part of BIM information now, and the role of contractor to provide and import information into BIM should be improved. The effort of contractors and sub-contractors in updating BIM information and its richness is critical for maintenance period. In addition, the result shows that there exist many challenges that hinder pragmatists to migrate from level 1 BIM to level 2 BIM implementation. In addition, there are challenges that exist for conservative to follow pragmatists in adopting higher level of BIM in their projects. The results show that as the adoption of BIM goes to a higher level the more complex challenges face, thus proving the hypothesis.

The study contributes in the body of knowledge by deepen understanding of challenges of BIM implementation in construction projects. In addition, the results reveal that there are two waves of BIM adoption. In each wave, conservatives face challenges to follow pragmatists in adopting higher level of adoption. Pragmatists also face nine challenges to shift from level 1 to higher level of BIM usage in construction projects.

The results of the study help the industry policy makers who encourage contractors to use higher level of BIM by resolving the challenges and provide more supportive resources or infrastructure for contractors to cope the challenges. The study will expand to investigate more contractors and other AEC companies to continue to uncover more in-depth challenges. Future recommendations include comparing the levels and types of challenges faced in different countries. Additionally, this research will explore solutions to these problems, such as the use of standards or ontologies to promote interoperability. Furthermore, the study will investigate the recent trends of using the Semantic Web to share ontologically based information over the internet for use in BIM applications.

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