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Investigation of Readiness for 4D and 5D BIM Adoption in the Australian Construction Industry

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ABSTRACT

As Building Information Modelling (BIM) is an enabler that can improve productivity of a construction project by facilitating collaboration among stakeholders, there has been an effort to promote BIM adoption in Australia, and yet the Australian construction industry is remained behind in adopting the BIM

capabilities related to time (4D BIM) and cost management (5D BIM). In order to identify current barriers and potential recommendations for promoting BIM uptake, this research conducted a questionnaire survey and interviews focusing on 4D and 5D BIM adoption in the Australian construction industry. Consequently, it is identified that the Australian construction industry is not fully ready to embrace 4D and 5D BIM capabilities since basic 3D BIM capability related to 3D visualization is the main usage of BIM for construction projects. As major barriers, a lack of demand from clients for BIM use and high initial costs for BIM system setup are identified. More importantly, a lack of guidance to construct an information-enriched BIM model is recognized to move forward to the next level of BIM utilization such as 4D and 5D BIM capabilities. This research serves as a stepping-stone to study further to promoting BIM uptake in the Australian construction industry.

Keywords: BIM, 4D BIM, 5D BIM, Australian Construction Industry

INTRODUCTION

It has been a central issue for construction customers to maximise value, lower cost and achieve sustainability in an industry that has been criticised for its inefficiency and lack of productivity. This inefficiency results in delays in the project schedule, budget and scope, and eventually causes a quality compromised product with a higher price (HZ, 2007). According to the National Institute of Standards and Technology (2004), $15.8 billion per annum is estimated to be spent due to inadequate interoperability among project stakeholders based on different

software systems in the capital facilities sector of the US construction industry. Despite the current inefficiency in the construction industry, recent customers' design requirements have become more irregular and bespoke. These are difficult to be presented in a two-dimensional manner, and require more productive ways to manage the clients' design needs from the outset of a construction project.

As a response to the increasing complexity of construction projects and a demand for productivity improvement, information and communication technology such as Building Information Modelling (BIM) has been introduced to manage, as well as achieve, sustainability in construction projects (Taxén and Lilliesköld, 2008; Gaith et al, 2012). Building Information Modelling (BIM) is defined as an information management system to integrate and manage various construction information throughout the entire construction project life cycle based on a 3D parametric design to facilitate effective communication among project stakeholders to achieve a project goal(s) in a collaborative manner (Kim, 2014). The purpose of this research is to identify if the current Australian construction industry is ready to adopt BIM technology by following the current trend of global construction industry.

BIM ENGAGEMENT STATUS IN AUSTRALIA

Various benefits of BIM are identified, and three major benefits are commonly mentioned in the literature: 1) Design Quality Improvement, 2) Productivity Improvement (Effective and Efficient Project Information Management) and 3) Sustainability Enhancement (Eastman et al., 2011; Hannele et al., 2012; Froese, 2010). 3D parametric representation is a fundamental distinctive capability of BIM, and there are different

capabilities of BIM that are described in a nD capabilities based on 3D BIM capability as shown in Table 1 (Eastman et al., 2011). 4D BIM capability can establish links between project activities and the 3D building elements that enables construction professionals to conduct the constructability check before the construction phase (Eastman et al., 2011).

Table 1. nD BIM Capability

nD BIM	Capability	Description
3D BIM	3D Model	Project visualization, Clash detection
4D BIM	3D + Time	Schedule visualization, Construction Planning
5D BIM	4D + Cost	Quantity Take-offs, Real Time Cost Estimating
6D BIM	5D + Facility Management	Life cycle management, Data Capturing/Monitoring

5D BIM is capable of managing costs throughout a project life cycle including cost estimation and budgeting. In particular, quantity surveyors and cost estimators can reduce time and efforts on quantity measurement and development of bill of quality, and moreover can improve the accuracy of cost estimation (Hannele et al., 2012; Froese, 2010). Consequently, BIM is regarded as a major paradigm shift in the construction industry (Hannele et al., 2012; Succar, 2009), and currently developed countries such as US, UK, and South Korea strive to adopt BIM relentlessly by establishing the BIM strategies and mandates as shown in Table 2. The US government established a national 3D-4D BIM program to increase BIM uptake for public office building design and operation led by the General Services

Administration. The UK and the South Korean governments have introduced and promoted BIM in the construction industry by mandating BIM use for all public construction projects (HM Government, 2012).

Table 2. BIM Engagement Status Comparison

	US	UK	South Korea	Australia
BIM Mandate Year	2006	2016	2016	None
BIM Strategy	3D-4D BIM Program	Push and Pull	BIM Roadmap	National BIM Initiative
BIM Standard	AIA E202 BIM Protocol	PAS 1192 series	Public Procurement BIM Guideline	National BIM Guide
BIM Champion (Initiation Year)	GSA, 2003	OGC, 2010	MLTMA, 2010	NATSPEC, 2011

Note: GSA - General Services Administration,
OGC - Office of Government Commerce,
MLTMA - Ministry of Land, Transport and Maritime Affairs,
NATSPEC - National Specification System of Australia

Nevertheless, Australia has been stalled behind in the BIM adoption status because there have been no follow-up efforts to mandate BIM adoption or develop specific national BIM standards like others. Comparing with high level of public drivers' involvement in other countries, the engagement of BIM driven by the government initiatives is currently limited. Although the

government led initiatives are limited, there are various regional and city based BIM hubs such as Australasian Procurement and Construction Council, Australian Construction Industry Forum, and city based organisations such as BrisBIM (Brisbane), MelBIM (Melbourne), and buildingSMART (Sydney).

In alignment with a nation-wide level of efforts, the National Building Information Modelling Initiative strategy was established in 2012 to promote the adoption of BIM and relevant digital technologies in the Australian built environment sector. Furthermore, there is an increasing number of studies conducted focusing on the adoption and implementation of BIM within the Australian construction industry such as NATSPEC National BIM Guide, National Guidelines for Digital Modelling and Collaborative Design Education using BIM (CODEBIM). As a result, the current proficiency in the usage of 3D BIM capability in Australia is no less than other continents such as North America, Europe, and Asia (Jung and Lee, 2015).

However, the advanced BIM usages, which are 4D and 5D BIM capabilities, are still remained low compared to other continents such as North America and Europe as shown in Table 3 (Jung and Lee, 2015).

Table 3. Advanced BIM Usage Comparison

Continent	North America	Europe	Asia	Australia
3D Modelling	81.8%	60.7%	67.6%	88.9%
4D Scheduling	54.4%	57.1%	18.9%	33.3%
5D Cost Estimation	95.5%	92.9%	56.8%	66.7%

There are commonly identified barriers in further BIM adoption within the construction industry as shown in Table 4

(Park and Kim; 2014; Eadie et al., 2013; Kim and Park, 2016), and inevitable barriers to adopt new technology and processes such as cultural resistance and learning curve have been well identified (Joo and Lee, 2006; Chai and Chai, 2007; Mohapatra and Dash, 2011).

Table 4. Barriers of BIM Adoption

Categories	Description
Business and Legal Barrier	· Ambiguity in data ownership and legal risks · Lack of clarity on roles and responsibilities · Lack of clients/market demands · High investment cost and low incentives · Return on Investment
Technical Barrier	· Lack of standards · Interoperability · BIM Library/Dataset
Organizational Barrier	· Lack of initiative and training · Resistance to changing current practices · Lack of knowledge/data library

There have been a few studies about BIM in the Australian construction industry, and yet specific barriers related to the Australian construction industry context have been limitedly researched. According to Smith (2014), it is identified that insufficient amount of investment has been made to adopt 4D and 5D BIM (Smith, 2014; Olantunji et al., 2010). Overall BIM adoption in 4D and 5D capabilities within the Australian construction industry is limited, and Aibinu and Venkatsh (2012) emphasized that insufficient ICT developments and supports

associated with Australian Quantity Surveying (QS), which is directly related to 4d and 5D BIM practices have been made to accommodate QS professionals' dynamic demands and automated quantities measurement trends.

Although, there have been a few attempts to integrate the advanced BIM capability within large construction companies in Australia, the 4D and 5D BIM adoption and implementation are still rare. Aibinu and Venkatsh (2012) attempted to explain the root causes of slow adoption in advanced BIM capabilities, but this research is limited to provide a general issue in the perception of construction industry regarding BIM. Alabdulqader et al. (2013) identified barriers of general BIM adoption: a) resistance to change; b) lack of interoperability; and c) upfront cost, and yet it fails to provide specific grasp regarding the slow adoption of 4D and 5D in the Australia construction industry context.

Thus, this research aims to investigate the readiness of BIM adoption focusing on specific 4D and 5D BIM aspects, and to provide a clear understanding of current challenges in adopting the advanced BIM capabilities in the Australian construction industry. This research is expected to provide practical insights for organisations to utilize BIM further and serve as a stepping stone to move forward to the advanced BIM-enabled construction industry in Australia.

METHODOLOGY

This research consists of semi-structured interviews with a web-based questionnaire survey. Since this research is specifically confined to the Australian construction sector to understand to obtain specific viewpoints and in-depth insights regarding 'what is the current status of BIM adoption' and 'how

can advanced BIM capabilities be adopted' in the Australian construction industry in real life context, questionnaire survey for quantified outcomes in conjunction with interviews for in-depth contextual insights are essentially adopted as a mixed method approach (Creswell et al., 2004). The questions adopted a 5 point Likert scale since it is the most popular method among researchers and easy to communicate with respondents (Knight and Ruddock, 2008; Chimi and Russell, 2009).

In order to obtain valid and relevant research findings, 68 prequalified construction professionals, who are actively involved in a BIM-enabled construction project and employed in a nation-wide construction company such as Rider Levitt Bucknall and Mitchell Brandtman, are selected via construction professional organizations such as Royal Institution of Chartered Surveyors (RICS), Australian Institute of Building (AIB), and Australian Institute of Quantity Surveyors (AIQS).

The web-based questionnaire was comprised of 15 questions designed to explore the following three key aspects; a) awareness and current status of BIM, b) perceived advantages and barriers to BIM adoption, and c) current readiness for 4D and 5D BIM capabilities adoption. A pilot questionnaire survey was conducted prior to the main questionnaire survey to eliminate misleading questions, ambiguity and any difficulty in responding (Polit et al., 2001). After the completion of questionnaire surveys, follow-up semi-structured interviews were conducted.

RESULTS AND DISCUSSION

Total 68 prequalified professionals were contacted and the response rate was 38% (26 out of 68). As shown in Table 5, the profile of respondents indicates a wide range of roles. The average experience of using BIM for their practice is 4 years, and 19% of

respondents (5 respondents) indicate that they have more than 6 years of experience with BIM.

Table 5. Profile of Respondents (Total 26 Respondents)

Role	Number of Respondents	Percentage (%)
Quantity Surveyor	10	38
Project Manager	6	23
Construction Manager	6	23
Building Estimator	3	12
Business Development Manager	1	4
Total	26	100

Awareness and Current Status of BIM

39% of respondents (10 respondents on Level 4 and 5) indicate that BIM is highly recognized in their organization in terms of benefits of 4D and 5D BIM capabilities. On the other hand, 35% of respondents (9 respondents on Level 1 and 2) indicate that BIM has been rarely or even unrecognized in their organizations as shown in Table 6, which reflects the low BIM adoption in the Australian construction industry.

Table 6. Level of BIM Awareness in Organization

BIM Awareness	Lv1	Lv2	Lv3	Lv4	Lv5	Total
Number of Respondents	3	6	7	9	1	26
Percentages (%)	12	23	27	35	4	100

Note: Lv1= Unaware, Lv5= Highly Aware

Those who indicate as Level 3, which is neutral, provide supplementary comments that they are aware of BIM benefits, and yet they have not implemented or planned to adopt BIM in their practice. In addition, respondents commented that there should be a person serving as a BIM adoption champion in order to increase awareness and uptake of BIM within an organization, and lead an organization to embrace BIM practices.

Follow-up questions are asked to identify what kinds of capabilities of BIM are mainly utilized for their projects in their organisations by allowing multiple choices. As shown in Table 7, the responses are evenly distributed across various capabilities. Clash detection, Concept Design Planning, and Cost Estimating functions have received relatively high recognition among respondents' organisations.

Based on this finding, it can be considered that currently BIM is utilized more frequently for the early design phase and constructability check compared to project planning and controlling such as project scheduling and cost control. Six respondents who indicated 'Not Applicable' commonly commented that BIM is mainly used for a visual-aid purpose, and clients do not require further BIM implementation in a project. Furthermore, since respondents utilize customized in-house 2D measuring tools and scheduling tools such as MS Project and Primavera, they mentioned BIM is not applicable for them.

Table 7. Primary Capabilities of BIM

Capabilities of BIM	Numbers of Respondents	Percentages (%)
Clash Detection	10	40
Concept Design Planning	9	36
Cost Estimating	6	24
Not Applicable	6	24
Project Management	6	24
Cost Planning	5	20
Cost Control	4	16
Project Scheduling	1	12

However, they clearly emphasized that they are fully aware of BIM usage due to the engagement with other project participants such as architect and engineers, but information for quantity measurement and scheduling has provided a format that is compatible with their in-house tools, which is mainly 2D based drawings and specifications. Thus, it can be extrapolated that the current BIM usage in the Australian construction industry is a mixture of 2D drawings and 3D BIM.

Advantages and Barriers of Advanced BIM Adoption

Respondents are asked to indicate their opinions regarding the advantages and barriers of BIM adoption in order of priorities. As identified through literature review, the full capabilities of BIM have not been explored and utilized, and it is proven the first priority use of BIM focuses on 'Better Visualization' as shown in Table 8.

Table 8. Advantages of BIM Adoption

Advantages	Numbers of Respondents
Better Visualization	24
Improved Design Coordination (Clash Detection)	20
Whole Life Asset Management	15
Reduced Project Costs and Duration	10
Enhanced Team Collaboration	7

The advantages of advanced BIM capabilities adoption such as 'Whole Life Asset Management' and 'Reduced Time and Costs' are ranked in the lower priorities. The findings reflect the research findings (See Table 3) that the Australian construction industry is relatively slow in adoption of advanced BIM capabilities such as cost estimation and project scheduling.

Table 9. Barriers of BIM Adoption

Barriers	Numbers of Respondents
High Setup Costs	20
Lack of Client Demand	20
Resistance/Reluctance to Adopt New Technology	18
Extra Efforts for BIM Model Development	17
Incompatibility with Standard Methods of Measurement	12
Lack of Quality Datasets	9
Lack of Government Intervention	7

92% of respondents (24 respondents) are aware of the 3D visualization capability of BIM and better coordination through clash detection, which is mainly related to 3D visualization capability of BIM. After addressing fundamental advantages of BIM inherited from 3D parametric modelling nature, respondents mentioned that they have limited experience in 4D and 5D BIM capabilities.

Respondents addressed barriers such as the high upfront cost for establishing BIM systems and a lack of demand or interest from clients, which impede the active implementation or investment in BIM system. It is important to note that there are no huge numerical differences among the identified barriers from rank 1 to 4. From this finding, it can be extrapolated that the current low BIM adoption or limited exploration of advanced BIM capabilities in the Australian construction industry is not caused by only one single reason such as high upfront cost, but it is caused by complex reasons which are a combination of various barriers including a lack of demands and reluctance of team members in an organisation.

Thus, it is important to consider mutual efforts to adopt and explore advanced BIM capabilities in both sides – clients and construction professionals. More interestingly, through the interviews, it is commonly pointed that construction professionals face challenges since there is no common cost database to measure the bill of quantity, which is addressed as Rank 5 and 6 in the questionnaire survey. In particular, QS professionals have to build up their own cost databases and the database is not interoperable across the supply chain as other project stakeholders including contractors, sub-contractors, and manufacturers using their own cost estimation software. There were other concern and comments on the transition between the 2D based practice and the 3D BIM based system. Currently, the

Australian construction industry uses the mix of 2D and 3D based system. Interviewees share the common experiences that they encountered when they implemented 5D BIM in QS practices, which is a poor quality BIM model with inaccurate cost information. According to interviewees, it took a longer time to spot BIM objects with inaccurate information and rectifies it for quantity take-off in a BIM system compare to using 2D based drawing in the first place. All of the interviewees emphasized the importance of quality BIM models and BIM objects with accurate information.

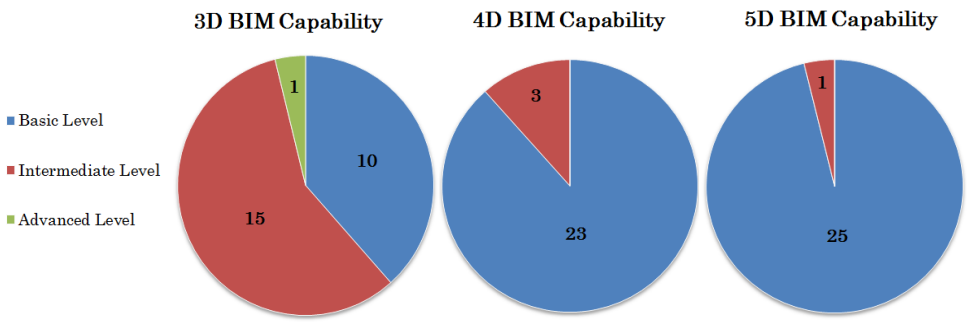
Furthermore, government intervention or policy based push is required as similar to other countries such as the UK, US, and South Korea to increase the uptake of BIM usage and appreciate the full capabilities of BIM. The responses from interviewees exactly echo with the findings from the literature review that there is a lack of government-led effort on mandating BIM for public construction projects, even though interviewees commonly mentioned that the BIM uptake will be possibly increased by either clients' demands or government's intervention.

Current Readiness for Advanced BIM Adoption

As shown in Figure 1, respondents are asked to indicate the level of BIM adoption in their organizations, and most of them indicate that they are at the intermediate level to utilize 3D BIM capability.

In contrast with 3D BIM capability, most of the respondents indicate that the adoption of 4D and 5D BIM capabilities has remained at a basic level. Based on this finding, the Australian construction industry is not fully ready to embrace the advanced 4D and 5D BIM capability, although there is an indication that an effort has been made at a minimum level as 4 respondents addressed that their organization is in the intermediate level of

4D and 5D BIM capability.



BIM Adoption Level	Basic Level	Intermediate Level	Advanced Level
3D BIM	10	15	1
4D BIM	23	3	None
5D BIM	25	1	None

Figure 1. Level of BIM Adoption (Number of respondents)

However, it needs to be noticed that the 4D and 5D BIM capabilities are not actually practiced in respondents' organization. The respondents commonly mentioned that they hire cost and scheduling consulting firms or consultants to utilize 4D and 5D BIM capabilities on behalf of the employer company, and arguably the interviewees mentioned the practice is a norm

in the industry. The interviewees are quantity surveyors, construction manager, and cost estimator with average six years of experience in 4D and 5D BIM in Australia. Interviewees commonly addressed that a lack of demand from clients constricts the construction industry to adopt and explore BIM more actively. An interviewee commented that the most of the clients are satisfied with 3D visualization of buildings. In addition, there were arguments that contractors and sub-contractors are also not pleased to utilize BIM over 2D based system, and they are reluctant to change their practices in accordance with the BIM system without any proper compensations or incentives. It can be considered that BIM needs to be adopted and practiced across the supply chain for a full experience of BIM capabilities. For increasing uptake of BIM, one interviewee stated that mutual efforts or agreements must be made between clients and construction professionals before a project starts because clients do not want additional financial expenses and construction professionals want to be compensated reading additional time and efforts to utilize BIM, which is very unlikely if there was no agreement from the beginning.

Additional Comments and Reflections

Two interviewees, a construction manager, and a project manager, addressed that the current BIM-enabled processes induce delays on project schedule since the processes between BIM model management and project management are entangled. For this reason, there are redundant efforts to coordinate project works and BIM related works, and consequently, delays on the project schedule occur. During the interview, two interviewees are asked if they are aware of BIM standards such as PAS 1192:2 or NATSPEC National BIM Guide, and yet they failed to confirm acknowledging the BIM guides. Indeed, PAS 1192:2 explicitly

explain the roles and responsibilities of a BIM manager as well as a project manager in a BIM-enabled project environment. Based on this findings, it can be argued that collective efforts to educate the construction industry and provide more relevant and practical knowledge and skills to construction professionals or an organization. Additionally, interviewees are asked to indicate how long they think it will take 4D and 5D BIM is positioned in the centre of QS practices, and the average of the period was 5-10 years. More active government intervention and standardized guidelines such as a standard method for measurement are mentioned as an essential stepping-stone of promoting BIM in the Australian construction industry.

CONCLUSION

Currently, the construction industry around the world focuses on practical and advanced BIM capabilities implementation to improve productivity and enhance sustainability in the built environment. There has been an effort to promote the BIM adoption in the Australian construction industry by releasing proper guidelines for BIM, and yet the Australian construction industry is remained behind in adopting the advanced BIM capabilities compare to other countries such as US and UK. In order to identify current barriers and possible solution to promote BIM uptake in the Australian construction industry, this research conducted a questionnaire survey and interviews focusing on 4D and 5D BIM adoption in the Australian construction industry. Consequently, it is identified that the Australian construction industry is not fully ready to embrace 4D and 5D BIM capabilities since basic 3D BIM capability is the main usage of BIM for construction projects which is demanded by clients at present. As major barriers, a lack of demand from

clients for BIM use and high initial costs for BIM system setup are identified. Based on the findings, it can be understood that there is a vicious cycle presented between clients and the construction industry as clients do not want to use the advanced BIM capabilities, and the construction industry does not want to make an investment. Furthermore, a lack of guidance to construct an information-enriched BIM model is recognized to move forward to the next level of BIM utilization such as 4D and 5D BIM capability.

This research reveals that the current slow adoption of advanced BIM capabilities is not caused by one single reason, but induced by a complicated combination of reasons. In order to resolve current issues and move forward to the digital construction era, it is highly recommended to encourage BIM demands from the clients, support investments for advanced BIM use in the construction industry, and make proper government interventions in the development of standards and BIM datasets. This research is expected to provide a stepping-stone to study further to promoting the uptake of advanced BIM capabilities in the Australian construction industry by providing a fundamental and in-depth appreciation of current BIM readiness of the Australian construction industry.

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