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Review of the use and development of Building Information Modelling software in the Architectural and Engineering industry - an Australian Perspective

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Abstract

Building Information Modelling (BIM) has the potential to significantly improve design, construction and asset management in the Architectural and Engineering (AE) industry, including optimising the life cycle of constructed facilities, and improving their ongoing sustainable development and operation. While the main focus to date of BIM development has been on its dimensional characteristics and its maturity levels, a greater understanding is required of how well industry is using this software in design.

Research has accordingly been undertaken into the use of BIM as a management tool in the AE industry in South East Queensland, Australia, focusing primarily on SME businesses, with the purpose of identifying the extent of BIM use in design software, better understanding how BIM modelling software is used in the design process, and better aiding the discovery of improved pathways for its implementation. Achieving these goals can assist government and BIM enablers to facilitate the development of a common standard to aid industry participants to improve information sharing, collaboration and improved performance, thus impacting on positive built environment life cycle aspects like interoperability, design consistency, and improving sustainable development and management.

The results of a mixed methods questionnaire, which consisted of a number of Likert scale questions, plus a number of short answer qualitative questions, which was sent to industry respondents on the use of BIM in the AE industry in South East Queensland suggest that while BIM has been quite widely adopted in the industry, SME businesses in the AE industry demonstrate relatively slow development in their use of BIM software. In addition, its functionality can be better utilized, and BIM can be diversified to include a greater range of users. While Government mandates of BIM would be likely to increase the use of BIM across the industry, respondents felt that such mandates should be implemented cautiously and with industry guidance, so as to not force unachievable goals which could be damage the increased adoption and use of BIM in the industry.

INTRODUCTION

Building Information Modelling (BIM) has been used in the architectural, engineering and construction (AEC) industry for a number of years. It may be formally defined as “use of a shared representation of a built asset to facilitate design, construction and operations process to form a reliable basis for decisions” (International Organization for Standardization, 2018, p. 5). Another view of BIM is "a multidimensional, historically evolving and complex phenomenon" (Miettinen & Paavola, 2014). Thus BIM provides a digital model of a facility that ideally is shared over the life of that facility and is continually developing into a significant information technology tool within the AEC industry.

Since its inception, the main focus of BIM has been to develop the Architectural, Engineering and Construction industry construction industry from the use of two dimensional drawings to a digital model that considers the life cycle of a building or infrastructure development. It has the potential to significantly improve design, construction and asset management, including optimising the life cycle of constructed facilities, and improving their ongoing sustainable development and operation. While the emphasis to date of BIM development has been on its dimensional characteristics and its maturity levels, a greater understanding is required of how well industry is using this software in design.

Through discussing its application in South East Queensland, Australia (SEQ), this paper considers how BIM modelling software is being used, with a focus on Small and Medium Enterprise (SME) organisations (which in Australia are normally firms that employ less than 200 staff), to develop the models that are the basic building blocks of BIM. The research discussed in it thus differs from much of previous BIM research that has been more focused on the adoption, dimensions and maturity levels of BIM, which has developed considerably beyond the description system originally developed into three dimensional (3D) parametric models that which facilitate the use of the same objects at different scales and facilitate increased efficiencies. In particular, it focuses on the capabilities of BIM as modelling software. It therefore aims is to review how the architectural and engineering (AE) industry is using the available BIM modelling software to facilitate a BIM environment, and whether the software used is truly a BIM tool or a more efficient two dimensional (2D) computer aided design (CAD) tool.

The research discussed in the paper has considered the following:

- How BIM is developing and being used in the architectural and engineering design (AE) industry in South East Queensland.
- Whether the AE industry in this region is satisfied with how BIM software performs.
- Whether competent users of BIM are developing partnerships with other users
- An indirect assessment of the maturity of BIM within the surveyed community.

These requirements are further developed in Figure 1, which sets out the processes followed in the research discussed in this paper.

LITERATURE REVIEW

While BIM is increasingly used in the AEC industry, not all software used in building design should be considered as a BIM system, particularly when used as modelling software. For example, Eastman et al. (2011, p. 15) state that, according to the process or techniques being

used, the tool or software to create 3D BIM model, may not necessarily be constituted as BIM. Examples include models that contain 3D data only and no object attributes, that have no support of behaviour (i.e., do not utilise parametric properties of objects), are composed of multiple 2D CAD reference files that must be combined to define the building, or allow changes to dimensions in one view that are not automatically reflected in other views (i.e., make errors in models hard to detect). This view is not universal. For example, Onur and Nouban (2019) included Sketch Up, which does not have smart or parametric objects, as a BIM software technology.

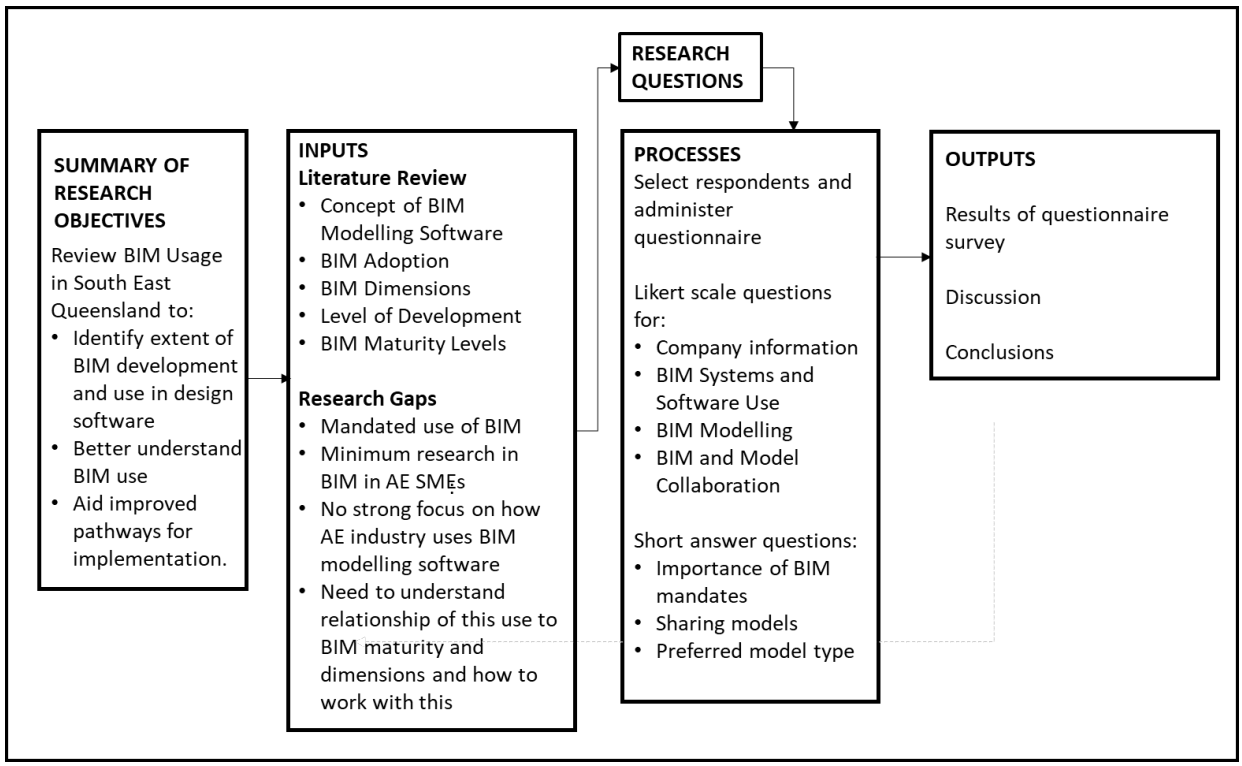

Figure 1, Conceptual Framework of Research

From the point of view of adoption of BIM, Yalcinkaya and Singh (2015) found that many studies have primarily considered the challenges associated with the adoption and implementation of BIM, implementation of BIM related to project delivery, and management processes and stakeholder realisation of the benefit of BIM. There are also other factors that are impacting on the widespread adoption of BIM technologies. For example, while there is a definition of BIM, there tends to be a lack of a standard or legal definition for BIM professionals and their responsibilities (Rokooei, 2015). For example, there are issues with the intellectual property and ownership or copyright to a design in an integrated virtual BIM model (Wilkinson and Haywood, 2018).

While BIM initially commenced as a three-dimensional model, which can express visually and in other ways the three primary spatial dimensions of width, height and depth, it has later 4D (planning) and 5D (costing) dimensions, and has also developed additional dimensions such as sustainability and facilities management (Charef, et al., 2018). These authors also found that while there is agreement within industry about the first five dimensions of the BIM model, there was less understanding about higher level dimensions, a finding supported

by Lu et al. (2017), who found that the use of BIM for facilities management (FM) during the operational phase is still limited.

A related concept is the level of development and detail that a model should contain, including guidelines for the sharing and collaboration of BIM models. According to the BIMForum, an association promoting an open forum for the advancement and collaboration of BIM, the Level of Development (LOD) Specification is 'a reference that enables practitioners in the AEC Industry to specify and articulate with a high level of clarity the content and reliability of Building Information Models (BIMs).' These levels are contained in level of development specifications that use basic LOD definitions developed by the American Institute of Architects (BIMForum 2020).

A further concept in the use of BIM is the development of BIM practices and standards for categorising and measuring the progress of BIM within the industry, which uses frameworks to measure the capabilities of BIM by an individual or company. An example of this approach is that of Bew and Richards (cited in Succar, 2009), who have defined define maturity models for the use of BIM. Their model consists of four maturity phases, ranging from Phase zero, which is software for CAD drafting, to Phases 1 and 2 are the stages at which BIM modelling software is being used (the design and build phase of the works) to Phase 3, where all information, both designed and constructed are being shared as an integrated and available source for facilities management and the life cycle of the works.

The mandate of Governments to use BIM has been a significant factor in facilitating the adoption of BIM in other countries. In Australia, the Australian Standing Committee on Infrastructure, Transport and Cities provided a report for Parliament into the role of smart Information Communication and Technologies (ICT) (Parliament of Australia, 2016). The Queensland Government released a document in 2018 outlining principles for BIM Implementation (Department of State Development, Manufacturing, Infrastructure and Planning, 2018) which outlined a strategy to support an open BIM environment, including to support and further BIM implementation on major state infrastructure projects from July 2019. Given these initiatives, while Governments in Australia, although not mandating BIM levels or expectations, are supporting an 'Open BIM' environment. In turn, the OpenBIM Alliance of Australia supports an open BIM exchange (buildingSMART Australasia, 2020).

The literature review has found that BIM adoption, dimensions, maturity and implementation are widely researched topics. However, BIM research, such as its barriers to adoption, has tended to focus on larger organizations rather than small and medium enterprise companies (SMEs) (Hosseini et al., 2016). Similarly, there does not appear to be a strong focus on how the AE industry uses BIM modelling software for the creation of a building model and how this relates to the Maturity or Dimension of BIM. In addition, in order to make full use of BIM in areas like asset management and sustainable development, consultants and others in the industry will eventually be required to work with the higher level dimensions of BIM beyond scheduling and costing. Finally, the position with respect to mandating BIM use in Australia is unclear.

To address these research gaps, the research discussed in this paper focused on the measurement, in the SME sector, of the use of the BIM as a modelling system rather than the software being used to implement BIM. Its focus was on SME organisations in South East Queensland, Australia. It also considered how the AE industry uses a BIM modelling tool for

the creation of a building model and how this relates to the Maturity or Dimension of BIM. It was considered that it would be important that the research used a broad range of AE industry representatives to gain a better understanding of the use of BIM and its use by industry as a modelling system. It is contended that the ability to gauge or find pathways to a greater BIM maturity and ways to measure the BIM implementation in the AE industry will assist with more widespread BIM adoption.

METHODOLOGY

The research used mixed methods to gather data, using a questionnaire that was approved by the Human Research Ethics Committee of the University of Southern Queensland.

Items that had varying levels of response were assessed using a Likert scale of 1 to 5. Examples of such questions included the use of a BIM modelling system, how information was input into and/or used in the software and whether the system allowed for this process. Limitations of Likert scales, such as the possibility that the answer can be compromised by social desirability (McLeod, 2008), were recognised and addressed as much as possible through providing opportunity for anonymity by respondents.

Short answer qualitative questions were asked about a number of selected topics. There was also an opportunity for respondents to provide feedback about the survey, and to obtain views from respondents about their companies' implementation of BIM, their thoughts about the use of BIM software, and the current state of BIM in the AE community in SEQ.

In order to aid triangulation, and hence better understand issues like data convergence, or alternatively the presence of inconsistency or contradictory data (Mathison, 2020), questions focused on as broad an analysis of the data as possible. In addition, the qualitative portion of the survey gave respondents the opportunity to respond regarding the question asked.

The study focused on SME industry participants involved with the design and coordination of the built form, which includes all types of buildings as defined by the classification provided in the National Construction Code of Australia (NCC) by the Australian Building Codes Board (2019). These participants were those AE industry participants who were more likely to be using a BIM modelling system. They included the following groups:

- Architects (and in particular project architects), who lead the design of the built form.
- Engineers, and in particular structural, electrical and mechanical engineers involved in building design.

Because of their role in implementation rather than design, and their use primarily of project management and estimating scheduling BIM related software rather than the more advanced modelling systems, constructors were not included in the survey. They are a potential future group for this type of study.

In line with the desire to have as broad an analysis group as possible, a mixture of targeted and random participants within the AE industry in South East Queensland was used. The use of targeted participants was also expected to aid with a more successful completion rate of the survey. The random group aided with broadening the survey. They were identified through professional engineering and architectural associations, and BIM user groups.

Questions asked of participants were structured as follows:

- Question Group A: Basic Information- AE Company Profile
- Question Group B: BIM Systems and Software Use
- Question Group C: BIM Modelling
- Question Group D: BIM and Model Collaboration
- Question Group E: Short Answer Qualitative Questions.

RESULTS

Introduction

The questionnaire was emailed to 100 potential participants. Of these participants, three did not wish to complete the questionnaire, and there were 25 responses in total. The questionnaire was re-sent twice. While the number of responses can be considered small for a statistical analysis, it is considered reasonable for this research, which focuses on the number and frequency of responses only for a given set of parameters rather than a full statistical analysis. Respondent organisations were classified on the basis of 0-5; 6-20; 21-50, 50-100; and 100 + employees.

While some responses were “yes” or ”no”, the majority of questions used a five point Likert scale tailored to the responses requested. The response options were: agreement (strongly disagree, disagree, neutral, agree, strongly agree); frequency never, rarely, sometimes, very often and all the time); and importance (unimportant, of little importance, moderately important, Important and very important).

Overview

From the participant group 20 (80%) were identified as using a BIM modelling software tool and 5 (20%), which were primarily smaller Architectural and Engineering companies, were identified as not using this type of tool (see Table 1). Three companies sampled were larger architectural firms with over 100 employees. All other firms had 50 or fewer employees. The reason for their not using BIM tools, as defined for this study, is unknown. One explanation could be that the types of work that these companies were undertaking did not require the use of BIM tools.

Most companies surveyed had been using BIM modelling software for more than five years, which indicates a strong uptake in SEQ of the use of it in the built environment. With respect to software, architectural and building design companies were the only participants using ArchiCAD, whereas Revit was being used by all industries represented, being the most widely used BIM modelling software. Other software included MicroStation (used by a minority of engineering design companies). Sketchup Pro was only used by one architectural company. The results provide a good indication of how the more popular BIM modelling system programs are being used and which industry group is using them. At the same time, if the questionnaire had been sent to a wider group of organisations (such as government and infrastructure designers), the results may have been different.

Table 1, Number of Companies in Industry Groups by Size using BIM Modelling Software

Response	No Employees	Industry Group	Number of firms giving the response
NO	0-5	Architectural	1
NO		Engineering	2
NO	6-20	Engineering	2
YES	0-5	Architectural	2
YES		Building Design	2
YES		Engineering	4
YES	6-20	Architectural	1
YES		Engineering	1
YES	21-50	Architectural	1
YES		Building Design	1
YES		Engineering	4
YES	51-100	Engineering	1
YES	100+	Architectural	3
TOTAL			25

Total number of firms giving "NO" response – 5 firms

Total number of forms giving "YES" response – 20 firms

BIM Systems and Software Use

Questions in this group were aimed at determining how BIM modelling systems were being developed by the participant's organisation and the use made of the software in project models. Firms not using BIM software would have been unlikely to answer these questions.

The first set of questions in the group included the issues in transition from a 2D to a 3D model, the use of BIM and BIM processes on projects (to which), use of drafting standards within the firm and the management and development of BIM in the organization. The results indicated that while the transition from 2D to 3D was not easy, more than half of the participants were using BIM, participant firms were using appropriate standards, firms were regularly checking their building models to check that these standards were being followed, and that there was well-developed and strategic use of BIM modelling software within the industry to assist firms to further develop the use of the BIM tool. As the use of BIM systems by firms grew, the need for BIM manager became evident, particularly in larger companies.

A second set of questions in this group focused on the firm's knowledge and understanding of the Level of Development (LOD) with respect to a Building Model object or element. While it was generally agreed that a higher LOD in a 3D object is normally required to reduce 2D drafting and documentation, there was less agreement on whether the LOD was being used to further the parametric capabilities of 3D objects.

The final question in this group asked whether the BIM enabled software platform used made it easy to enable LOD in the building models created by the participant firm. This question was an indicator to the possible direction of future growth in sharing BIM information over the built asset lifecycle, thus aiding not only time and schedule management, but also facilitating the use of the higher order dimensions of BIM that had the

ability to be used for asset, safety and sustainability management. The results for a question in the survey with respect to whether the BIM enabled software platform that respondents used made it easy to enable LOD in the building models that they created, are shown in Figure 2. While seven of the 16 firms that responded to this question agreed with it and two strongly agreed with it, seven firms were neutral, which suggested this was not a straightforward process, even though most participants had been using a BIM modelling tool for over five years.

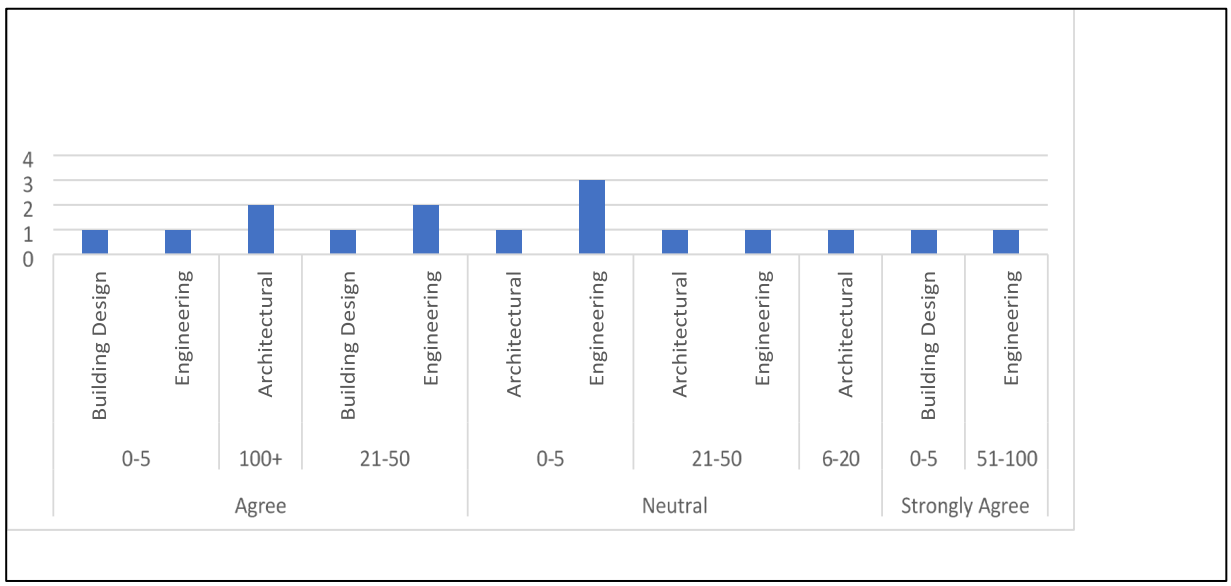

Figure 2, Response to Survey question - The BIM enabled software platform we use makes it easy to enable LOD in the building models we create.

Source: van Neuren, C. (2020) Bachelor of Engineering (Honours) Thesis, University of Southern Queensland, Toowoomba, Queensland, Australia.

BIM Modelling

The questions in this group were aimed at how the AE industry participants were using BIM modelling software to model their projects and considered the common modelling tool and techniques that are available within most BIM modelling system programs. The experience of the first author with respect to using such systems was related to benchmarks in setting up building models to compare with their use by others, and that it was considered important to set out buildings and other engineering infrastructure to provide geospatial data. It was found that while some participants used this approach, it was not common practice, even though it can facilitate 'real world' requirements in models, such as earthworks calculations where surveys had been provided.

In some cases, BIM software was not always used to produce 3D models when only a 2D model was required. However, firms that did produce such models for more than documentation reasons appeared to further develop their BIM modelling capabilities. While there was a mixed response to questions asking whether project specific data was being added to modelling objects to enable scheduling, there appeared to be a tendency, particularly among smaller firms that do not have well defined libraries of modelling objects, to add this data. It was also noted that models were being created to an extent that the data

created from them can be used as an indication of project elements that can be used for scheduling and costing (4D and 5D models). Inbuilt sustainability tools within BIM modelling software, such as for estimating energy efficiencies or sun studies, were not often used.

BIM and Model Collaboration

This group of questions asked how users were sharing or using other consultants' models, if they were sharing models and the preference of the model type that was being shared.

Generally, respondents were not usually using another consultants' model, even in the native format of their own BIM modelling system. At the same time, respondents appeared to be using cloud sharing models, such use highlighting that companies do have processes in place to manage projects of this type. While most companies also would have preferred to use or create their own 3D BIM model rather than that of another company, the participants believed that there was benefit from sharing models and that model sharing is identified with furthering the BIM environment provide better project outcomes. There were also some negative results for this question, indicating that in some instances collaboration may have been less successful than initially perceived.

Additional questions focused on the use of native data files of the same software used by different organisations. From responses to these questions, it was concluded that this approach was seen as important by respondents and that therefore they understood that, in collaboration between consultants using BIM modelling software, techniques like model sharing enabled them to work together effectively.

An example of responses to questions in this section was that to a question that asked whether sharing models in any format was found by respondents to be the best way to facilitate a better project outcome for them and the client, as shown in Figure 3. Of the 15 firms that responded to this question, four (two building design firms and two engineering firms) considered that this occurred all the time, five (three architectural firms and two engineering firms) considered that this occurred very often and five (two architectural firms, one building design firm and two engineering firms) considered that this was sometimes. One smaller engineering firm responded that this was the case rarely. Thus the responses by the 15 firms that answered this question were generally quite positive, indicating that most considered that that sharing BIM models achieved a positive outcome for the client. Other firms had a mixed view, possibly as a result of their software not allowing sharing to occur easily, or they had sometimes did not have a positive result from sharing models.

Short Answer Questions

The final question group was a set of short answer questions that used a combination of quantitative and qualitative questions, to which respondents were requested to optionally provide a comment. They included the following:

1. The importance of BIM mandates in Australia.
2. Whether Industry clients/partners had expressed interest or requested the use of a building model for facilities management purposes from the company.
3. The maximum dimension of BIM that the respondent believe they had used in a project.
4. Preference to work with consultants using the same BIM enabled software.

5. Whether interoperability between projects, open BIM and sharing IFC (Industry Foundation Class) models meant the respondent was required to re-model and update models regularly.
6. Which industry sector the respondent believed was most progressing BIM.

With respect to BIM mandates, the responses were mixed. Comments included:

- *'BIM is such a broad term and the expectations from parties that do not understand it can be vastly different to what the industry can provide.'*
- *'Support, but the economic reality of implementation is always forgotten in this discussion.'*
- *'Europe has accelerated ahead of the US because of Mandates.'*

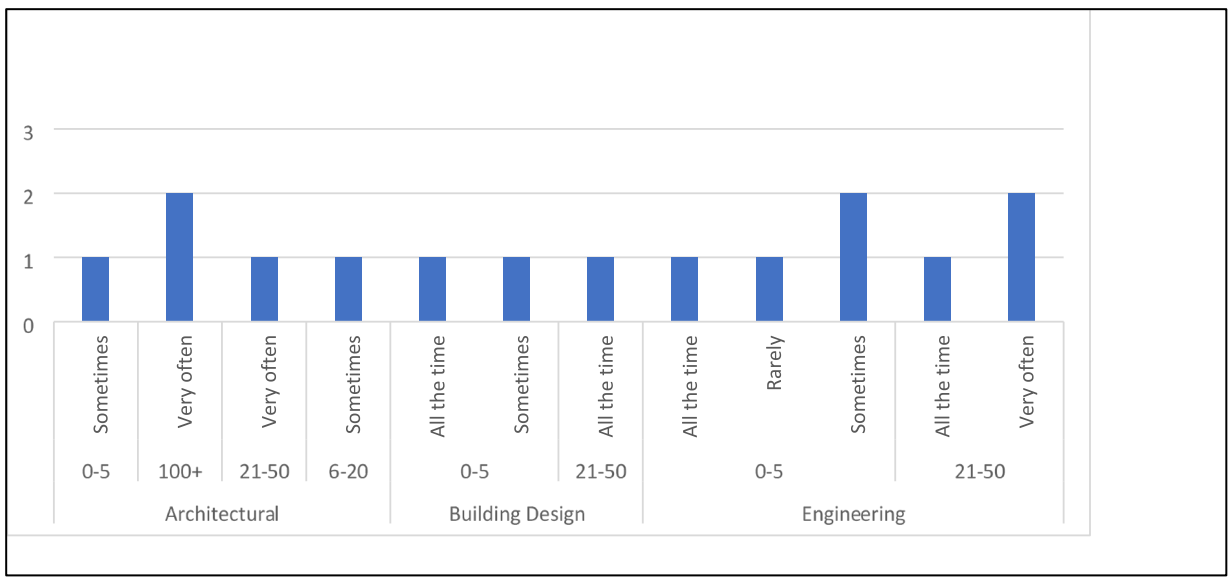

Figure 3, Response to Survey question – Sharing models (any format) we find to be the best way to facilitate a better project outcome for us and the client.

Source: van Neuren, C. (2020) Bachelor of Engineering (Honours) Thesis, University of Southern Queensland, Toowoomba, Queensland, Australia.

The answers to Question 2 above (whether there has been a request for a BIM model for facilities management purposes) was mixed. They respondents also felt that most clients were happy with a 3D model, particularly one that was animated, while the data in a higher dimensional model does not align with such ideas. This concept is supported by the answer to Question 3 (the maximum dimension of BIM used in a project), which tended to be, with a few exceptions, 3D. These answers indicate that the use of BIM modelling for asset and sustainability modelling in the surveyed area may not occur for some time.

Most respondents indicated that they preferred to work with consultants using the same BIM enabled software (Question 4). With respect to Question 5, which further explored interoperability between BIM and IFC enabled models, the answer was mixed, suggesting that the question may have been interpreted differently by participants. One interesting response was whether the extent of coordination and changes, expected or required, should be considered when scoping works (i.e., as a part of the fee), an important point as the question could be asked at what stage does making changes to a model start becoming an

additional or unfactored cost. This factor can also impact on the required LOD in BIM modelling software, as different LODs can be required for the phases of a project (for example, construction and asset management). Finally, the response to Question 6 (what industry sector was considered to be progressing the BIM environment in South East Queensland) varied with the respondent's industry. It was concluded that all industry sectors are responsible for this development.

Answers to a final question relating to the understanding by respondents of the questions in the survey and their relevance to industry resulted in generally positive results, thus indicating the questionnaire was relevant to respondents. An interesting comment in the responses to this question, which covered several of the aspects asked in the questions in this section was:

'The mandating of BIM, while a fantastic outcome would need some caveats in my opinion. For commercial project it is a feasible possibility to create the models, however the concern comes as to how the models remain updated in high maintenance environments…. For residential projects, my concern is financial feasibility...While I think mandating BIM is a good idea, I think a measured approach is required to ensure it is applicable and of use.'

A comment from another respondent was:

'To improve the BIM industry, further marketing should be targeted at the 5th/6th dimension - i.e. end user and having them interact with the model, changing wall colours, furniture etc via mobile app. Further development in this will quickly push investment and the need for BIM and make it standard for the integration of the virtual world with the real world assisting augmented reality.'

Both of these comments are considered relevant to the future of BIM and its use as modelling software, and identify the need for a considered approach to mandating its use and marketing the use and importance of its higher dimensions, which are required for its used in asset and maintenance management, and in facilitating sustainable development.

DISCUSSION

Discussion of Results

The questionnaire was designed to follow the logical sequence of basic company data, adoption of BIM systems and their use, development and creation (BIM modelling), collaboration and opinions on selected questions.

A positive finding was that 20 of the 25 companies responding to the survey used a BIM modelling system tool, and that such tools were being used by companies of varied types and sizes. As companies that did not use such a tool tended to be in the smaller range, a possible conclusion could be that smaller companies may not find it easy to adopt BIM systems.

The adoption of a BIM modelling platform from traditional 2D CAD programs was found not to be always easy, with only four (4) participants stating that it was not difficult. Some firms also found that it may not always be easy for staff to adapt to BIM. At the same time, companies that adopted BIM modelling tended to further develop its capabilities over time. In accordance with this view, companies generally understood the term 'level of development' (LOD), with companies using a BIM modelling system for five or more years creating objects with an understanding that the objects could serve more than one purpose,

and that they were using higher dimensions of BIM like 4D (scheduling) and 5D (estimating costs).

With respect to model development and creation, while participants would usually model surfaces and topography, they would not often use this modelling for placing the model in a 'real world' environment, such as using geospatial location of the model. A possible explanation for this practice was that this sector of the AE industry may have considered this task unnecessary and one which may affect project budgets.

The questions with respect to collaboration of BIM modelling software with other consultants provided an opportunity to consider the use of such programs and the maturity levels of participants. Results from these questions gave rise to further questions about the concept of an 'Open BIM Platform' (BuildingSMART Australasia, 2020), which is a significant question for considering whether an open BIM workflow could contribute to furthering the dimension of BIM past 3D.

There were mixed views with respect to Government mandates on the use of BIM, with a tendency to support such mandates provided they are implemented cautiously and with industry guidance, so as to not force unachievable goals which could be damage the increased adoption and use of BIM in the industry. Industry collaboration being a possible conduit to enable mandates to be introduced effectively was suggested.

Overall, the results of the research show that there is mixed opinion about the use of the BIM software tools in the AE industry, and the extent to which it can be developed. However, there are several companies now using this software for up to 5D, these dimensions of BIM being an important aspect of the link between the dimension developed and the goals of participants.

Relationship with findings of other research

The research discussed in this paper has been reviewed against the literature on BIM, and in particular its development and use by the SME sector of industry. As discussed in the literature review, BIM is being extended beyond three dimensional design into not only planning and costing, but also into sustainability and facilities management (Charef et al., 2018). The development of this capability, as well as other uses such as the facilitation of automation, robotics, and 3D printing (Kouch et al., 2018), requires considerable development of the modelling capabilities of BIM. The survey responses shown in Figure 2 of this paper, which indicated that reaching a higher level of development in BIM modelling was not a straightforward process, suggest that developing the necessary skills in BIM to achieve its ability to support sustainability and facilities management will take time.

One of the issues with the development of BIM that much of the research into its development and use has been focused on larger organisations and its adoption by them, as previously discussed in the literature review. This paper has a focus on the SME sector, which as observed by Saka and Chan (2020), is under-represented in BIM research studies. Studies of the type discussed in this paper are important in filling this gap.

Research conducted by Arayici et al. (2011) into BIM adoption and implementation in architectural practices, using a knowledge transfer partnership that combined both the socio-technical and socio-cultural approaches, with the aim of achieving lean design, underscored the importance of communication and collaboration in the effective used of BIM in design.

The results in Figure 3 in this paper showed the importance of sharing models as the best way to facilitate a better project outcome for both clients and consultants. Further support to the importance of collaboration is given by the discussions of a conceptual model for improving BIM usage and acceptance within SMEs through organisational, relationship, human and technology factors (Makarfi and Udeaja, 2019), and by research conducted by Vidalakis et al. (2019) into BIM adoption and support, with a focus in SMEs, that knowledge exchange initiatives would facilitate further implementation of BIM.

As indicated by the response in this paper to short answer questions, cost was also a factor in areas like interoperability, a finding reflected in a study by Hosseini (2016), who found that one of the main barriers to the adoption of BIM adoption by Australian construction SMEs was an uncertain return on investment. Cost was also a factor in the research conducted by Vidalakis et al. (2019).

Therefore, the results of the research discussed in this paper, which is considered to have made a strong contribution to the understanding of the development and use of BIM in the SME design sector, with an Australian focus, are largely consistent with other research into the use and development of BIM in the SME sector, both in Australia and in other jurisdictions, such as the United Kingdom.

CONCLUSIONS

This research has indicated that while was a quite high adoption of BIM and use of BIM modelling software tools across the AE industry in South East Queensland, there are also varying views about the usefulness of this software as some participants are still attempting to see the benefit and return on investment since this adoption. It was, for example, noted that the objects within the BIM modelling software tool are being used and developed for both 2D and 3D parametric advancement in BIM. Such development tends to maintain use of 2D systems.

Therefore, based on the responses by the organisations surveyed, the use of BIM modelling software in the SME sector of the AE industry in SEQ is currently in the hands of individual organisations. As it becomes more widely used, there will be questions about other topics, such as the best software to use, compatibility, sharing models and interoperability. Education, standards and sharing the use of BIM modelling software are also important in advancing the use of BIM, as is making the software more accessible.

It is recommended that government and industry further consider options for mandating the use of BIM in Australia, along with the ways in which this process could be managed. Careful planning, including industry discussion and reviewing how mandates have been implemented elsewhere, will be required to implement any mandate, which has the potential to further develop the use of BIM. An Open BIM approach would facilitate this process.

A potential area of further research is the facilitation of the use and development of BIM models for increased used by the SME sector in the architectural, engineering and construction sectors though processes such as Open BIM development, education and the wider use of BIM models in design, and practical approaches to extending BIM modelling to other dimensions of development, such as asset management and sustainability. Achieving these goals will require developing higher levels of BIM modelling software, increased use of geospatial coordinates, and further investment in ongoing software development and use.

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