AWARENESS, USAGE AND BENEFITS OF BUILDING INFORMATION MODELLING (BIM) ADOPTION – THE CASE OF THE SOUTH AUSTRALIAN CONSTRUCTION ORGANISATIONS

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Research has shown that while Building information modelling (BIM) is not a new concept, and that its uptake is becoming an increasingly important factor in the efficiency and international competitiveness of the Australian construction industry (ACI), when compared with other industries, the ACI is often regarded as being slow to implement new ideas and technologies. Furthermore, they are limited studies conducted which seek to assess the current levels of awareness, usage and advocated benefits of BIM among construction organisations, within the context of South Australia. The study is aimed at filling that knowledge gap. The objectives of this study were to: (1) ascertain the current awareness and determine usage rates of BIM adoption; and (2) establish the advocated benefits relating to the adoption of BIM relative to its impact on project outcomes among the stakeholders of the South Australian construction industry. A field study was conducted with a randomly selected sample of twenty-nine construction organisations. Ten BIM benefits were used, and survey response data were collected using structured questionnaires and analysed using mean and ranking analysis. Relative to the awareness and usage, the findings indicates that a significant proportion of respondents have little or no understanding on the concept of BIM and the usage was found to be very low. The results indicated that 'improved constructability', 'improved visualisation', 'improved productivity', and 'reduced clashes' as the highly ranked benefits associated with BIM adoption. The highly ranked major issues surrounding the adopting or use of BIM were 'lack of understanding about BIM', 'education & training costs' 'start-up costs' and 'changing the way firms do business'. The practical implication for Senior Managers within the construction organisations are that; awareness of BIM processes through education and training; both formal and informal process including more information, and provision of expertise within BIM could enhance the levels of adoption.

Keywords: modelling, awareness, construction industry, South Australia

INTRODUCTION

Despite the importance of the construction industry as a key player in Australia's economic development as evidenced by its contribution (in excess of 6%) to Gross Domestic Product (GDP) and employing nearly 1 million people (Australian Bureau of Statistics 2010), compared with other industries, it is often regarded as being slow

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to implement new ideas and technologies, which have the potential to make it a much more competitive and productive industry.

Furthermore the construction industry is inherently fragmented, partly due to the once-off nature of most construction projects, often meaning project teams, processes and ideas learned previously are not relevant for the next project and also because of the competitive environment that often exists between disciplines. This fragmentation can result in poor information flow and poor collaboration between disciplines ultimately leading to inefficiencies in productivity. The need for the industry to embrace change is highlighted in a report by the Department of Innovation, Industry, Science and Research (2010) which indicates the uptake of technologies such as Building Information Modelling (BIM) are 'becoming an increasingly important factor in the efficiency and international competitiveness of the Australian construction industry.' The report explains that 'international activity indicates global markets view BIM as an important tool for the future growth and competitiveness of the built environment.' The above observation calls for the further exploration into the possible adoption of BIM among the construction organisations in South Australia.

OBJECTIVE

The objectives of the study were as follows:

- To ascertain the current awareness of BIM by members of the SA construction industry.
- Determine the current usage rates of BIM by stakeholders of the SA construction industry
- Explore the SA construction industry member's perception on the problems and benefits surrounding the adoption and usage of BIM and identify solutions to address key issues.

Due to non-availability of documented and structured data on BIM awareness, usage and benefits with the Department of Planning, Transport and Infrastructure (DPTI) prequalified Category 1, 2 and 3 builders and trade contractors for the study, questionnaire survey was used for the data collection. The responses received were statistically analysed.

LITERATURE SURVEY

Adoption, awareness and usage issues

A number of studies have reported on the reluctance of the construction industry to adopt new technologies (Yang, 2007; Lawrence and Scanlan, 2007; Gambatese and Hallowell, 2011; and Sargent *et al.* 2002). For example, a study by Yang (2007) which explored the links between technology usage and project outcomes, found that, when compared to other industries, the construction industry was less reluctant in the application of new technologies. Similarly, Gambatese and Hallowell (2011) study aimed at investigating the varying differences in the rate of technical innovation throughout the construction industry, found 'fear of change' among the inhibitors to this diffusion. Similarly, within the context of small and medium enterprises (SMEs), Hardie and Newell (2011) conducted a study aimed at determining whether any common lesson could be drawn from the experience of individuals, who had managed to successfully implement or deploy the technical innovation. The study identified a number of factors that enabled construction innovation. These were as follows: (1) company resources; (2) client and end user influence; (3) project-based conditions; (4)

Industry networks; and (5) regulatory climate. These enablers were further classified into fifteen sub-factors using analytic hierarchy process methodology.

Other studies conducted within the Australian context such as Kymmell (2008), Gerrard *et al.* (2010), BIM in Australia (2010) have attributed the following barriers as contributing to the low level of awareness and poor uptake of BIM: 'Poor collaboration and trust between stakeholders in the construction industry' 'lack of trained staff', 'lack of understanding', and 'implementation costs of BIM'. A study by Arayici *et al.* (2011) aimed at presenting a systematic approach for BIM implementation found the people, process and technology as crucial for its success.

Challenges and Benefits

A number of studies such as CRC for Construction Innovation, (2007); Jordani (2008); Allen Consulting Group (2010; BIM in Australia (2010); Underwood and Isikdag (2011) have highlighted the potential benefits to be gained from the adoption of BIM. For example, a study by Allen Consulting Group (2010) established a number of benefits resulting from the implementation of BIM technology. These included the following: improved information sharing enhanced productivity, improved quality, and increased sustainability and labour market improvements. Each of these benefits has significant flow on effects which ultimately result in a much more competitive industry along with the more efficient use of resources and also a higher quality building. Other notable benefits arising from BIM as indentified by the same study (Allen Consulting Group, 2010) included the following: 1) 'Better design', 2) 'Controlled whole-life costs and environmental data', 3) 'Enhanced processes', 4) 'Higher production quality', 5)' Improved customer service', and 6) Life-cycle data. Similarly, a study by BIM in Australia (2010) highlighted increased efficiencies, improved productivity and enhanced communication between and within teams as major benefits that can arise from the introduction of BIM.

According to Underwood and Isikdag (2011), there is scope for BIM in future directions such as improving the way facilities are managed through applications of data sensors, known as WSN's (Wireless Sensor Networks). Accordingly, these WSN's can be achieved through their installation into building elements. However, Underwood and Isikdag (2011), explains that 'in order to get the greatest benefit from BIM technology it must be used as a facilities management tool.' This was also earlier identified by Jordani (2008) who pointed out that, the many benefits possible with BIM are rendered practically useless unless the information is further utilized in Facilities Management (FM). 'Simply delivering project BIM's to an owner has marginal value. To be effective, the data captured in BIM's must be channelled into a variety of FM software systems'. It is assumed Jordani's opinion is based on the fact that the major cost involved in a facility is not its construction but the operation and running costs during its life-cycle where the use of BIM technology will prove to be most beneficial. Other benefits identified in literature have ranged from 'enhanced visualisation' (Kymmell, 2008), 'improved productivity' to 'enhanced sustainability of construction industry' (CRC for Construction Innovation, 2007).

RESEARCH METHODS

As the main objectives of this study were to ascertain the current awareness and determine usage rates of BIM adoption, with a view to establishing the advocated benefits relating to the adoption of BIM to the impact on project outcomes, the following research methodology was employed in the study.

Instrument

The questionnaire was divided into four sections as follows: 1) general demographics of the respondents and awareness / usage issues; (2) BIM enabler's; (3) barriers and challenges to BIM adoption; and (4) benefits of adoption BIM. Each item in the BIM enabler instrument was measured from a range of (1) representing not important to (5) representing highly important. Thus, (3) represented indifference, i.e. neither not important or highly important. The last section sought to measure the benefits of BIM adoption, and comprised ten items (see Table 1). Each item (barriers) was measured on a 5-point Likert format where 1 = not important and 5 = highly important. Thus (3) represented indifference, i.e. neither important nor not important.

Selection of Key Respondents

As the study sought to reveal the understanding and usage rates of BIM by stakeholders of the South Australian (SA) construction industry, the primary source of information was identified as being firms involved in the SA construction industry. In order to be able to infer research findings back to a population, and produce accurate and meaningful results, indicative of SA construction industry in general, an approach of random sampling from the Government of South Australia's Department of Planning, Transport and Infrastructure (DPTI) prequalified Category 1, 2 and 3 builders and trade contractors were selected (DPTI, 2011). These stakeholders were selected as they represent a broad cross-section of the SA construction industry (from $2M to $50M Australian dollars projects), allowing for accurate data relating to the awareness and usage rates of BIM in the SA construction industry to be collected. Another reason for the selection of stakeholder's from the SA Government's prequalification list, was that these firms would be more likely to be involved in a broad range of projects and potentially use more current technology, in order to remain competitive and ultimately sustainable

Reminder phone calls were also made approximately two weeks after the surveys were sent, resulting in four additional responses. In a related study, by Gerrard *et al.* (2010), a comparable approach to reduce the sample population was adopted for data collection purposes. These stakeholders were also chosen as they are more likely to be leaders in the industry, adopting change more readily than other smaller, less recognised firms. It is therefore, assumed that members from these companies may have a greater understanding of BIM and provides the researcher with more meaningful results.

Survey Administration

Because the purpose of the study were descriptive, and the research question involved establishing the opinions of respondents on BIM awareness , usage, benefits and challenges, according to Forza (2002), the recommended strategy is that of an analytical survey. To this end, survey questionnaires were used as the data collection technique.

A total of 75 questionnaires were sent out using a random sampling technique, which ensures bias is not introduced. Although 35 were returned, 4 were rejected because they were not completely filled out. The reasons provided by the returnees were that the study was not relevant to their business. A further 2 respondents indicated that some of the information required was 'confidential to their business; thus only 29 were included in the analysis for a response rate of 39%. This response rate is similar to previous studies within the construction (Shash 1993; and Kometa & Olomolaiye

1997) which obtained response rates of 28% and 23% respectively. The response rate was therefore deemed adequate for the purpose of data analysis. Akintoye and Fitzgerald (2000 cited in Odeyinka *et al.* 2008) argued that this is well above the norm of 20-30 % for postal questionnaire of the construction industry.

However, the high non-response rate (53.33%) also suggests that BIM wasn't relevant to their organisations, given that the targeted respondents were selected from the Department of Transportation, Energy and Infrastructure (DTEI) top three tiers of preferred building and trade contractors. This also, indicates a significant lack of interest and understanding of BIM and its potential benefits to their business and the SA construction industry

Statistical methods

As the purpose of the study was descriptive, frequency and ranking analysis were used (Forza, 2002). The *Statistical Package for Social Sciences* computer program was used to analyses the data thus collected. Furthermore, in order to transfer the responses obtained from the questionnaire surveys into accurate and meaningful data, the adoption of a relative importance index (RII) has been utilised where appropriate. The use of a RII, as a data analysis tool, has been used in other construction industry studies involving questionnaire surveys, such as Park (2009) and Tarawneh (2004).

SURVEY RESULTS

Sample profile

A total of professionals completed the questionnaire with the majority (20.69%; n = 6) drawn from Project Managers, followed by an equal number of Managing Directors (13.78%, n = 4). The rest were an equal number of marketing manager, design manager, estimator, administrator and project coordinator (3.45%; n = 1). Although the responses were not spread evenly throughout the roles, the results show that the sample population held significant positions in their organisations, and would therefore, be expected to have a good understanding of current practices and processes within their organisations and the wider construction industry.

BIM Usage Rates

This section reports on the use of BIM within South Australian construction organisations. The following question was posed to the respondents: *Is your firm currently using any form of BIM technology*? Only a minority (17.24%, n = 5) of the firms were currently using some level of BIM. Conversely, the majority, 24 (82.76%) reported as not using BIM. Given the low reported usage (17.24%, n = 5, of all the SA construction stakeholder respondents) of any form of BIM technology, the percentage responses reported here represent minority views. This finding contradicts the recent study by Allen Consulting Group (2010, pg 28), which found that from a total of 56 Australian engineering and construction contractors, 75% were currently using BIM. However, the results in our study are consistent with the earlier studies by Gerrard *et al.* (2010) and Kymmell (2008), which pointed out 'that there was currently a relatively low adoption rate of BIM in the Australian construction industry', but according to Kymmell (2008), it was 'approaching the tipping point'. Furthermore, a survey conducted by Gerrard *et al.* (2010, p 531) of Australian architecture, engineering and construction firms, revealed a usage rate of 7%. This appears to be more in-line with the questionnaire survey results, especially when the time laspes between surveys are taken into account.

Usage rates and Organisation Size

The data gathered also shows a link between the use of BIM and the size of the firm. The findings established that none of the firms with an annual turnover of less than $10 Million were currently using BIM. These results are consistent with literature which suggests that 'implementation costs of BIM were perceived by contractors, as potentially prohibitive in the short term' (BIM in Australia 2010, pg, 3).

Time since implementation of BIM

This section reports on the time elapsed since implementation use of BIM within South Australian construction organisations and whether the usage had increased or decreased. The results revealed that only a minority, (20.0%; *n* = 1) of the five firms had adopted BIM over four years ago, whilst the remainder have implemented it within the last two years. Furthermore, the results indicate that two (40.0%; *n* = 2) out of the five firms currently using BIM stated that, its usage had neither increased nor decreased since implementation. The remainder, (60.0%; *n* = 3) of BIM users however, indicated that its use on projects had increased since adoption within two respondents revealing that its use had increased significantly. Studies have shown that construction firms throughout Australia are only starting to become aware of the potential benefits of BIM and therefore, its use by most firms is only fairly recently. Furthermore, as previously highlighted by the Department of Innovation, Industry Science and Research (2010, p.2), 'the uptake of new technologies are becoming an increasingly important factor in the efficiency and international competitiveness of the Australian built environment industry'. Therefore firms are now more than ever turning to technology to remain competitive.

Industry understanding of the terminology 'BIM'

In order to achieve the first objective, namely that of 'ascertaining the current awareness of BIM by members of the SA construction industry', the respondents were asked the following question: How would you rate your understanding of the term BIM (Building Information Modelling)?' The respondents were asked to rate this understanding on a five-point Likert scale (where 1 = Never hear of, 2 = some knowledge; 3 = Fair (or moderate) knowledge; 4 = competent; and 5 = highly competent). The results showed that, a significant proportion (51.72%, n = 15) currently have either never heard of, or only have some knowledge of BIM. Whilst, only a combined total of (24.14%; n = 7) comprising BIM users (n = 3) and non-BIM users (n = 4) believed they had a moderate (or fair) knowledge of understanding. Significantly, only a minority, (3.45%; n = 1) of the respondents had a highly competent understanding of BIM. This respondent was drawn from the non-BIM utilisation organisation.

'Lack of understanding and awareness' was highlighted by Gerrard *et al.* (2010) and also by BIM in Australia (2010) as key barriers preventing more wide-spread adoption of BIM. Kymmell (2008) also reveal that there is a lack of understanding of what BIM is. These results therefore agree with literature that there is currently a genuine lack of understanding of BIM in the broader SA construction industry. A key point to note from the results, in terms of industry and awareness of BIM, was that, apart from one respondent, none of the remaining respondents whose firms were using BIM indicated they had more than a moderate knowledge of it.

Benefits associated with BIM Usage

Table 1 lists the ten benefits surrounding the adoption of BIM. The top four benefits (mean score > 4.0) were: 1) 'Improved constructability' (mean = 4.33, RII = 0.87), 2)

'Improved visualisation' (mean = 4.22, RII = 0.84), 3) 'Improved productivity' (mean = 4.07, RII = 0.82), and 4) 'Reduced clashes' (mean = 4.04, RII = 0.81).

Table 1: Means, Relative Importance Indices and Importance levels of the Benefits surrounding the adoption of BIM

Benefits	Mean[1]	RII (MS/5)	Importance level	Rank
Improved constructability	4.33	0.87	High	1
Improved visualisation	4.22	0.84	High	2
Improved productivity	4.07	0.82	High	3
Reduced clashes	4.04	0.81	High	4
Improved quality and accuracy	3.85	0.77	Medium	5
Improved client satisfaction	3.81	0.76	Medium	6
Increased competiveness	3.59	0.72	Medium	7
Improved information sharing	3.33	0.67	Medium	8
Improved sustainability	2.96	0.59	Low	9
Other reasons	1.00	0.20	Low	10

Notes: [1]: Likert scale values where 1 = Not important; 2 = low importance; 3= neutral; 4 = important; and 5 = highly important

The least important benefits, ranked eighth, ninth and tenth respectively were: 8) 'Improved information sharing' (mean = 3.33, RII = 0.67); 9) 'Improved sustainability' (mean = 2.96, RII = 0.59); and 10) 'Other reasons' (mean = 1.00, RII = 0.20).

DISCUSSION

Improved constructability

'Improved consructability' resulting in time, cost and quality benefit was the most highly ranked (mean = 4.33, RII= 0.87). This finding is consistent with other studies from CRC for Construction Innovation (2007); Jordani (2008) and Underwood & Isikdag (2010), which indicated th biggest benefit of BIM was the ability to have a complete and accurate set of documents for easy retrieval for the life of a facility, providing benefits not only during construction, but also throughout its life (such as facilities management tool). Similarily, improved constructability through lowered construction costs can be achieved through BIM adoption (CRC for Construction Innovation, 2007). Accordingly, the study (CRC for Construction Innovation, 2007) pointed to 'improved project efficiency' and also has the ability to 'prevent reworking', due to early pickup of issues such as clashes and other problems which may arise during construction.

Improved visualization

The second highly ranked benefit of BIM adoption was that of 'Improved visualization' (mean = 4.22, RII = 0.84). This finding is consistent with other studies from Kymmell, (2008) to CRC for Construction in Innovation (2007). For example, according to Kymmell (2008), the largest problem in the planning and construction process is incorrect visualization of the project. Kymmell (2008) further explains that, if a project is not fully visualized, understood and communicated, it cannot be represented correctly in the contract documents which may cause problems later in the construction process that will be much more costly to rectify. Similarly, a study by CRC for Construction Innovation (2007) acknowledges that one of the key benefits of BIM is its accurate geometrical representation of the parts of a building in an integrated data environment. Accordingly, this allows contractors to be much more accurate when ordering materials, helping prevent wastage and over-ordering. This not only provides significant cost savings on a project but also aids with the sustainability of construction industry by making the most of the world's precious resources.

Improved productivity

'Improved productivity' emerging as a result of improving collaboration between all parties involved in a project, including the client, designers and other professionals such as architects, engineers and contractors was the third ranked benefit (mean = 4.07, RII = 0.82). This finding is consistent with other studies such as CRC for Construction Innovation (2007), which indentified this aspect of 'improved productivity' as an important one in improving productivity of specific projects and industry in general. The study (CRC for Construction Innovation (2007), revealed that the use of BIM allowed for designers to work on a single model rather than having each member recreating and producing information. It also found clients gained a better understanding of the project via a 3D model containing information; this allows them to make more informed decisions on different options available to them by changing the project parameters and reviewing the resultant outcomes.

Reduced clashes

'Reduced clashes' resulting in reduce costly variations during construction and the ensuing delays which could result in liquidated damages being claimed resulting in time, cost and quality benefit was the fourth ranked benefit (mean = 4.04, RII = 0.81). According to a study conducted by BIM in Australia (2010), the application of BIM allows potential clashes between different trades or disciplines to be picked up early in the design phase. The resolution of clashes or inconsistencies between the works of different disciplines can also occur in the virtual environment, significantly shifting the time commitment for consultants from the construction phase back into the design phases, with resultant impacts on project team management and fee structures.

Improved productivity

Although this benefit of 'enhanced sustainability' was among the least ranked ones (mean = 2.96, RII = 0.59), its importance cannot be overlooked. As noted by CRC for Construction Innovation, (2007), 'enhanced sustainability, of the construction industry' has the potential of making the most of the world's precious resources.

IMPLICATIONS & LIMITATIONS

Implications

Based on the findings, the Senior Managers within the construction organisations are that; awareness of BIM processes through education and training; both formal and informal process including more information, and provision of expertise within BIM could enhance the levels of adoption. Based on the findings, one of the solutions aimed at to addressing the key issues surrounding the adoption and use of BIM by SA construction firms, is that there needs to be a concerted effort, though government and industry organisations, such as the Construction Industry Training Board in providing subsidised courses aimed at clients and industry leaders, educating them on the role BIM can play in the industry. Furthermore, as suggested by Hardie and Newell (2011), the regulatory climate under which the specific construction industry operates can act as a deterrent or agent of change (motivator). This study proposes that the South Australian construction industry makes it mandatory for construction organisations to have some form of BIM adoption as a requirement for bidding. Anecdotal evidence suggests that there is already a shift toward this requirement within the U.K

Limitations

Interpretation of these findings must consider the following study limitations. This study cannot be generalised statistically for the whole of the South Australian construction industry members as respondents were only drawn although from a random sample of the Government of South Australia's Department of Planning, Transport and Infrastructure (DPTI) prequalified Category 1, 2 and 3 builders and trade contractors.

CONCLUSIONS

This paper has presented the perceptions of the stakeholders representing the construction organisations in South Australia regarding the awareness, usage, challenges, and advocated benefits of adopting Building Information Modelling (BIM). The benefits identified from an extensive literature review have been analysed using descriptive statistics such as mean scores and standard deviation in order to rank their importance. Issues surrounding the adoption, usage and awareness levels were analysed using method of frequencies to measure the central tendency.

It can be concluded 'constructability' is viewed by the stakeholders as the highly ranked benefit that emanates from usage of BIM. The other highly ranked benefits were found to be 'improved visualisation', 'increased productivity' and 'a reduction in clashes'. The results indicate the least important benefit as that of 'the ability of BIM to increase sustainability. The most significant implication arising from this study is that the benefits surrounding BIM significantly outweigh its negative aspects. While there was a lack of adoption of BIM among the respondents, it was established that increased education and awareness of BIM needs to occur through the industry, in order for more wide-spread adoption to take place in South Australia. The study has provided some new insights into some of the reasons for the low awareness levels, slow uptake and the perceptions of the benefits of BIM related to the South Australian context

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