Factors influencing BIM Adoption in Small and Medium Sized Construction Organizations

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Abstract –

The advantages and disadvantages of Building Information Modelling adoption have been extensively investigated in available literature. However, the focus of previous studies has been placed mainly on BIM adoption in relatively large organizations and little effort has been made to investigate the effects that the size of the organizations may have on the BIM adoption process and its associated costs and benefits. This study aims to identify factors that affect the BIM adoption process in small and medium size construction organizations (SMOs) in terms of adoption motivations, ease of implementation and organizational competency. Quantitative and qualitative information are collected through survey and face-to-face interview of construction SMOs in Australia. Structural Equation Modelling is used to quantify the relationships between influential factors and organization's intention towards BIM utilization. The results presented in this paper aim to provide an insight into the needs and concerns of SMOs with regards to BIM adoption.

Keywords –

BIM adoption; small and medium sized construction organizations; influential factors

1 Introduction

Building Information Modelling has been advocated widely as a platform to enhance information communication, and reduce the project's costs and duration in the construction industry. Construction managers and engineers typically communicate with several parties involved in the project. Improved communication and exchange of technical information between the parties through BIM has been reported to affect project's productivity, quality and time [37]. National Institute of Standards and Technology reported an annual loss of $15.8 billion in the US, due to the lack of interoperability in the capital facilities. In addition, a variety of other benefits including project cost reduction and improved project team collaboration have been attributed to BIM adoption in construction [9,13,17,38]. However, apart from these associated benefits, BIM adoption in construction also faces a number of major challenges including difficulties in operating and maintaining BIM files, interoperability issues, and high implementation fee [3,25,28]. There is a great deal of literature on costs and benefits associated with BIM adoption process, the stages of the adoption process, and measures for effectiveness and maturity of BIM adoption and implementation [6,12,50]. However, previous studies have focused mainly on BIM adoption in relatively large organizations and little has been done to investigate the benefits and costs associated with BIM adoption as well as the BIM adoption motivations and challenges in small and medium sized organizations (SMOs). This is despite the fact that SMOs comprise the largest proportion of the construction industry. According to Australian government statistics [7], 97.8% construction firms are categorised as small business in Australia, and contributing 44.6% of the total market value. Despite the growth in clients' demand for BIM utilization, the adoption of BIM remains a big concern to SMOs [35,40].

This study contributes to the body of knowledge in construction technology adoption by identifying factors affecting BIM adoption decision in SMOs. This is achieved by analysing the results of a systematic survey and interview of 40 BIM professionals employed by SMOs across Australia. The results of this study can provide a basis for development of a decision making tool to assist SMOs managers to predict the outcome (i.e. adopt or reject) of BIM adoption in their organisation. This paper consists of four main sections: First, the available literature of advantages and disadvantages of BIM adoption in SMOs is reviewed. Second, the potential factors affecting the BIM adoption decision are categorised into three groups, viz. adoption motivation, ease of implementation, and organizational competency. Third, a generic BIM adoption model is presented and a number of hypotheses are developed. Finally, the results of a systematic survey conducted in Australia are analysed. SEM analysis and path analysis are presented and verifications are discussed.

2 Literature Review

2.1 Terms

This paper identifies factors which may affect BIM adoption in SMOs. The categorization criteria for SMOs vary from a country to another. European Commission (EU recommendation 2003/361) defines SMOs as companies with less than 250 full-time employees and an annual turnover of less than 50 million euros [18]. In China, the size of a construction company is determined by the number of its registered engineers (<60) and its total capital (<) [30]. Australian Bureau of Statistic [7] defines a small and medium-sized business as an activity trading business with 0-200 employees. In the present study the criterion used by Australian Bureau of Statistics is adopted to identify small and medium-sized contractors.

2.2 Advantages and Disadvantages

The costs and benefits associated with BIM implementation have been discussed in a number of previewed studies. However, the focus of such studies has been mostly placed on larger organizations. SMOs have considerable characteristic differences with larger organizations, which may affect the adoption process as well as the benefits and costs associated with the BIM adoption.

Based on the available literature, the advantages of BIM adoption by SMOs can be summarised in two main generic groups. 1) More organic organizational structure, which enables SMOs to have higher flexibility to change the existing working procedure. As Parida [19] pointed out, changing people's habits and getting them up to speed on a different technology is challenging especially for complex structured organizations. In larger organizations, all departments and levels have to face the challenge brought by working process change. 2) Smaller project size may help BIM implementation rate in SMOs to grow faster than in larger organizations [35]. Although SMOs are showing concerns about BIM's cost and applicability to their projects due to comparatively smaller size of projects, the size actually is a plus in driving higher levels of implementation. In larger organizations, a longer time is recognized to achieve complete and coordinate transition projects to BIM, because of the long project duration.

Furthermore, SMOs may not have enough budgets to afford BIM implementation and training expenses, as well as resources such as technical support [21,52]. Apart from above two disadvantages, the lack of understanding and knowledge of BIM in SMOs are obstacles to improve BIM implementation level within organizations [21,24].

3 Influential Factors

Based on the benefits and risks of BIM adoption, and theories of implementing innovations in construction industry, this study categorises influential factors in three groups – adoption motivation, organizational competency, and ease of implementation.

3.1 Adoption Motivation

During the innovation implementation process, the initial stage involves developing an awareness of the innovation and perceiving the needs to adopt the innovation [43,48]. Adriaanse, et al. [2] indicate that substantial benefits of implementing BIM in projects and external adoption motivations are key drivers for a company to approach BIM. In this study, in line with the existing literature on technology adoption the field of information technology, as discussed in the following, perceived usefulness of BIM implementation, organizational innovativeness, subjective norms, and awareness are categorised as major motivations of BIM adoption [33,52].

Perceived Usefulness (PU): This term was introduced by Davis [16], refers to the degree to which an individual believe that using a system would enhance his/her job performance. BIM utilization benefits not only individuals but also organizations [17,42]. Measures for PU include direct and indirect BIM implementation benefits in the organizational level. Direct benefits include reduced project costs and time, and improved team work; while indirect benefits mainly refer to intangible benefits, i.e. reputation, and benefits, which cannot be realized in short terms.

Innovativeness (IN): In a BIM acceptance study reported by Lee, et al. [33], this term was measured in two aspects: organizational innovativeness and individual innovativeness. A general survey of McGraw Hills Constructions [36] found that the innovativeness of an organization's leaders is a critical initiator of BIM adoption. Two proposed measures for innovativeness include the desire to build up organizational competiveness (IN1) and the need to streamline organization's workflow (IN2).

Subjective Norms (SN): Fishbein and Ajzen [19] defined this term as the person's perception that most people who are important to him think he should or should not perform the behaviour. Since in construction industry, activities are linked contractually, and contractual obligation is critical for an organization to accept new technologies [2]. Sexton and Barrett [47] found that one of motivations for small construction firms to implement innovations is survival in the market, which refers to the need for acceptance of technology as an operating necessity in the market. In this study, clients' requirement (SN1) and the need to share project information with other parties (SN2) are considered as key measures for SN.

Awareness (AW): Technology awareness is an essential component at early stages of implementation process [47,48]. A comprehensive understanding of innovations before decision making improves the efficiency of innovation implementation [43,48]. A study conducted by Parida, et al. [40] indicated that managers' knowledge of BIM has positive effects to BIM implementation. BIM awareness, in this study, is measured by the understanding of BIM definition (AW1), and knowledge of BIM applications (AW2).

3.2 Ease of Implementation

Technical issues have been highlighted by a number of studies as the main barrier affecting BIM adoption [1,25], especially in SMOs due to their limited resources [31,34]. The three primary factors contributing to ease of implementation include Ease of Operation, Ease of Maintenance, and Down Time.

Ease of Operation (EO): Also commonly termed as "ease of use" [27], this term refers to the degree to which an innovation is perceived as being difficult to use. The results of a survey reported by [52] and [38] indicate that difficulties in operating BIM are key barriers to BIM adoption. In this study EO is measured in terms of difficulties in learning process (EO1), model creation (EO2), and refining the project documentations (EO3).

Ease of Maintenance (EM): Maintenance for information systems generally refers to maintenance of applications, ongoing technical supports and upgrade (i.e. software and hardware). Maintenance is mentioned as an important factor for determining the cost of change management using BIM [29].

Down Time [27]: Down Time refers to a period of time that BIM fails to provide or perform its primary function either planned or unplanned [46]. The transition from traditional CAD drafting to BIM modelling causes higher requirements of hardware's capability. However, the tight budget may not allow SMOs to invest sufficiently in hardware upgrade [52]. Rogers, et al. [44] found that technical downtime contributed high probabilities to unsatisfied BIM implementation results. In this study, DT is measured in three aspects: the identification of DT as a risk (DT1), likelihood of DT occurrence (DT2), and consequence of DT occurrence (DT3)

3.3 Organizational Competency

Organizational competency can be measured in following areas: organizational support, expertise, and organization intention.

Organizational Support (OS): This term is defined as the degree to which an organization's policy supports BIM utilization [33]. Previous studies [40,49] show that top management support, including providing training (OS1) and encouraging staff to use BIM in daily work (OS2), is critical to BIM adoption.

Expertise (EP): BIM implementation is a complicated process, which requires professional technical skills [6,8,45]. The IT team plays a critical role in hardware selection, software installation, and ongoing support of the BIM implementation process. In project context, the variety of applied BIM software raise up issues in data interoperability [25,28]. Therefore, a technical support to shoot down relevant problems may improve the BIM implementation performance. In this study, expertise is measured by received professional support in hardware/software selection (EP1), and in BIM implementation (EP2).

Organizational Intention (OI): Fishbein and Ajzen [19], Davis [16] labelled this term as user acceptance, which is a prerequisite of actual use. Lee, et al. [33] estimated the organizational acceptance by the strength of willingness of an organization's intention to adopt, implement or recommend BIM to others. In the present study the organizational intention is considered to include intention to implement BIM into more projects (OI1) and to recommend BIM implementation to others (OI3).

4 Research Method

This study employed face-to-face interview and web based questionnaire to obtain quantitative and qualitative data. Interview helps to deeply understand industrial perspectives towards BIM adoption in SMOs. Questionnaire provides statistic basis to qualify relationships between influential factors and BIM adoption. The questionnaire uses 7-point Likert scale to measure each manifest variable. Research participants were chosen from senior personnel, managers, directors in SMOs with BIM knowledge. The research analysis was designed for a sample of 120 participants. At the first phase of this study, presented herein, a total of 40 responses were received.

The hypotheses of this study are tabulated in Table 1 and the hypothesises-based diagram is shown in Figure 1. This study employs Structural Equation Modelling to test the hypotheses. A two-step approach suggested by Anderson and Gerbing [5] is used to analyse SEM models, to reduce the potential model misspecifications. In the first step, the model's consistency, and the validate model's construct are assessed. The internal consistency of data is assessed using Cronbach's α value [15]. While the assessment of construct validate is performed by breaking the problem down to assessment of convergent validity and discriminant validity [14]. Convergent validity ensures that manifest variables measuring the same latent variable are demonstrating moderate inter-correlation; while an acceptable discriminant validity testing result requires independency among latent variables [20]. Convergent validity may be assessed using the following indicators: factor loading, composite reliability, and average variance extracted [10]. The most frequent way to examine discriminant validity is comparing the AVE value of a certain latent variable with the squared values of correlations between that latent variable and others latent variables [10]. The second step is hypotheses testing, based on proposed model (**Error! Reference source not found.**). Path analysis is employed in hypothesises testing. Path analysis decomposes effects into direct, indirect and total effects, [4].

Table 1 Hypothesises

Hypo thesis	Definition
H1	
a	Perceived Usefulness has a positive effect on Organizational Support
b	Innovativeness has a positive effect on Organizational Support
c	Awareness has a positive effect on Organizational Support
H2	
a	Perceived Usefulness has a positive effect on Organizational Intention
b	Innovativeness has a positive effect on Organizational Intention
c	Awareness has a positive effect on Organizational Intention
H3	
a	Ease of Operation has a positive effect on Organizational Intention
b	Ease of Maintenance has a positive effect on Organizational Intention
c	Down Time has a negative effect on Organizational Intention
H4	
a	Organizational Support has a positive effect on Ease of Operation
b	Organizational Support has a positive effect on Ease of Maintenance
c	Organizational Support has a negative effect on Down Time
H5	
a	Organizational Support has a positive effect on Organizational Intention

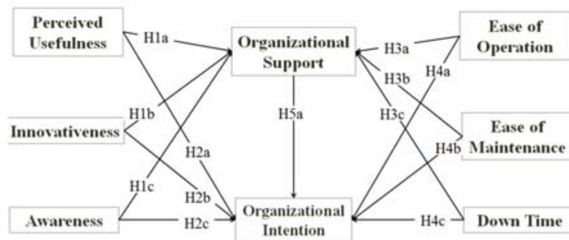

Figure 1. Organisation BIM adption model incldiuing heypotheses

5 Results of Validity Tests

Error! Reference source not found. presents the profile of respondents. 60% of participants involve with commercial and residential building projects; 45% of them are junior BIM operators with less than a year experience. The respondents were roughly reported an average rate of 38% BIM usage in their technical documentation process. 3D visualization, clash detection and quantity take-off are three applications which most frequently were used.

Table 2 Respondents' Profile

Characteristic		Statistics (%)
Business Type	Contractors	90.0%
	Consultants	7.5%
	Architects	2.5%
Number of Full-time Employees	0-4	15.0%
	5-19	17.5%
	20-199	60.0%
	200-499	7.5%
Project Type	Commercial	60.0%
	Residential	60.0%
	Public	27.5%
Years of Using BIM	Non users	37.5%
	6-12 months	7.5%
	1-2 years	32.5%
	2-5 years	22.5%

BIM Applications	3D Visualization	88.0%
	Clash Detection	68.0%
	Quantity Take-off	48.0%
Projects using BIM	Average Percentage	38%

Table 3 shows the Cronbach's α value for variables investigated in this study. As shown all the values, except for OI, are higher than the minimum acceptable threshold of 0.60 [39].

Table 3 Reliability Test

Latent Variable	Cronbach's α	No. of items
Awareness	0.777	2
Innovativeness	0.694	3
Perceived Usefulness	0.754	4
Organizational Support	0.847	4
Ease of Operation	0.731	3
Ease of Maintenance	0.864	3
Down Time	0.744	3
Organizational Intention	0.572	2

Table 4 presents the results of the convergent validity test. As shown, factor loadings of manifest variables to latent variables range from 0.456 to 1.043, composite reliability ranges from 0.573 to 0.862, and AVEs are between 0.402 and 0.701. The minimum acceptable threshold of these indicators are 0.5, 0.6, and 0.5, respectively [26].

Table 4 Convergent Validity

LV	MV	Factor loading	CR	AVE
Awareness	AW1	0.974	0.819	0.701
	AW2	0.673		
Innovativeness	IN1	0.456	0.744	0.509
	IN2	0.723		
	IN3	0.892		
Organizational Support	OS1	0.777	0.857	0.604
	OS2	0.601		
	EP1	0.849		
	EP2	0.855		
Ease of Operation	EO1	0.597	0.767	0.553
	EO2	0.462		
	EO3	1.043		
Ease of Maintenance	EM1	0.942	0.862	0.684
	EM2	0.908		
	EM3	0.582		
Down Time	DT1	0.922	0.720	0.479
	DT2	0.506		
	DT3	0.576		
Organizational Intention	OI1	0.605	0.573	0.402
	OI2	0.662		
Perceived Usefulness	PU3	0.704	0.769	0.460
	PU4	0.565		
	PU5	0.808		
	PU6	0.609		

The results of the discriminant validity test are shown in [10]. As shown, the results indicate high correlations for PU and EM, SN and OS, EM and EO.

Table 5. The values on the diagonal of the matrix are AVEs of each latent variable, while off-diagonal values are square values of correlations between the latent variable and other latent variables in its corresponding column. An acceptable level of discriminant validity requires AVEs greater than off-diagonal elements [10]. As shown, the results indicate high correlations for PU and EM, SN and OS, EM and EO.

Table 5 Discriminant Validity

	PU	OI	IN	EM	DT	OS	EO
PU	**.68**						
OI	.47	**.72**					
IN	.43	.38	**.71**				
EM	.69	.59	.57	**.83**			
DT	.49	.23	.23	.45	**.69**		
OS	.46	.37	.71	.68	.24	**.78**	
EO	.49	.61	.46	.90	.45	.48	**.74**

Model fitness indices of independent model and developed model were tested using six indices. The values for these indices as well as the recommended values are shown in Table 6[11].

Table 6 Goodness of Fit

Measure	Measurement model	Structural Model	Recommend value
$\chi 2/df$	1.861	1.976	≤ 3.0
RMR	0.259	0.324	≤ 0.10
RMSEA	0.149	0.158	≤ 0.10
TLI	0.599	0.545	≥ 0.80
CFI	0.674	0.611	≥ 0.80
PNFI	0.422	0.396	≥ 0.50

Table 7 decomposes the internal effects of variables into total, direct, and indirect effects. According to analysis results, AW, IN and EO have significant effects on OI; OS is significant to EO and EM; IN has significant indirect effects on EO, DT and EM. Meanwhile, Ease of Operation has been identified as a mediator which fully mediates the effects between OS and OI.

In general, while indicating a nearly acceptable performance for a majority of indicators, the results indicate the need for a higher number of data to further validate the results of the present study. The data collection is currently ongoing and will continue to meet all the validity and convergence criteria tested above.

Table 7 Total, Direct and Indirect Effects

		AW	PU	IN	OS	EO	DT	EM
Total Effect	OS	.03	.34*	.58***	0	0	0	0
	EO	.02	.20*	.34***	.60***	0	0	0
	DT	.01	.10	.18**	.31	0	0	0
	EM	.02	.25	.42***	.74***	0	0	0
	OI	.48**	.08	.38*	.21	.52**	-.09	-.001
Direct Effect	OS	.03	.34*	.58***	0	0	0	0
	EO	0	0	0	.60***	0	0	0
	DT	0	0	0	.31	0	0	0
	EM	0	0	0	.74***	0	0	0
	OI	.47**	.01	.26	-.07	.52**	-.09	-.001
Indirect Effect	OS	0	0	0	0	0	0	0
	EO	.02	.20*	.34***	0	0	0	0
	DT	.01	.10	.18**	0	0	0	0
	EM	.02	.25	.42***	0	0	0	0
	OI	.01	.07	.12	.28	0	0	0

*p<0.1, **p<0.05, ***p<0.01

6 Findings and Discussions

Findings of this paper are different to other studies in two ways. First, it examines different factors influencing BIM adoption in both individual and organizational levels; whereas, previous studies are mainly focused on BIM adoption at individual levels Peansupap and Walker [41] and Lee, et al. [33]. Second, the paper specifically investigates SMOs in the Australian construction industry using both quantitative and qualitative methods.

The results show that three main factors of 'Awareness', 'Innovativeness', and 'Ease of Operation' have been identified as critical factors that have been influenced the respondents' decision when considering to adopt or reject BIM . The result presented in Table 7 particularly show that Ease of Operation (β=0.52, $p<0.05$) is critical for individuals who contribute in the BIM adoption decisions, while Innovativeness (β=0.38, $p<0.10$), and Awareness (β=0.48, $p<0.05$) are vital for organizations. Since individuals contribute in the decision process, and the organisations should follow their procedures, both individual and organisational factors should be considered for BIM adoption prediction. Previous studies [33] mainly focus on the individual attributes and intentions in the BIM adoption decision, while the result shows that organizational supports have significant positive effects on two factors Ease of Operation (β=0.60, $p<0.01$) and Ease of Maintenance (β=0.74, $p<0.01$) by individuals.

Table 7 shows that Ease of Operation positively and fully mediates the positive relationship between Organizational Support (β=0.60, $p<0.01$) and Organizational Intention (β=0.52, $p<0.01$) [22]. The relationship is critical for BIM technology vendors and facilitators, because it shows the organisation intention toward BIM adoption is mainly affected by Ease of Operation and Maintenance. Surprisingly, the Organisation Support does not directly effects on Organisation Intention to use BIM. This is an important finding and refers to the fact that organisation support will be an influential factor if it effectively increases perceive of Ease of Operation. This is new to the literature, as it has been ignored in previous relevant literature. The insignificant correlation between EM and OI as shown in Table 7 indicates that most respondents don't think difficulties in maintaining BIM models and files would affect their decision about BIM adoption. Although this result is different with literature [3,25,28], SMOs may not experience BIM maintenance issues yet, due to smaller projects' sizes [15], and respondents' limited experiences in using BIM.

The result of the qualitative analysis shows that SMOs in Australia concern about organizations' competiveness and satisfying clients' requirements. According to respondents' feedbacks, influences from clients are initiations for SMOs to approach BIM. These influences not only include clients' requirement of BIM involvement in projects, but also include showcasing company's capability.

Except satisfying clients' requirements, displaying visualized video clips on our website is a kind of testimonial of our capability and profession.

My previous firm lost ten projects due to not using BIM.

However, because of the financial limitation, BIM implementation stays at the very basic stage e.g. drafting. Some SMOs are focusing on remodelling their previous project by using BIM, by adding Sketch-up. In ongoing projects, SMOs were found to suffer from unavailability of sufficient financial support in maintaining BIM models and files throughout the process.

We have amount of budget to do models on projects, mainly use an add-ins on program to Sketch up. But if we use BIM through the building cycle, it's gonna cost more, especially we started using BIM, operation skills are not mature.

This basic level of BIM implementation leads to lack of interoperation within a project. Suppliers are unable to extract information from contractors' deliveries, project information from architects are not consumed by contractors. However, the results also indicate that SMOs tend to be fresh in BIM implementation (45% respondents are with less than one year experience in BIM utilization), and getting SMOs involved into a collaborative working circumstance based on BIM needs a long time.

7 Conclusion

This study was aimed at identifying the factors that influence the BIM adoption decisions in SMOs. The results show that three main factors, viz. 'Awareness', 'Ease of operation', and 'Innovativeness' are critical factors influencing organisations decision to adopt or reject BIM. Furthermore, the qualitative data cross validate the results of the paper, and additionally indicates that complexity and compatibility are the main specific BIM implementation barriers.,

The results of this study also contribute to the body of knowledge by examining key factors (e.g. ease of operation and maintenance) influencing the SMOs' decision in the BIM adoption process, rather than focusing on factors (e.g. playfulness and anxiety) related to the individuals perception of information systems usage. The operation costs associated with BIM were identified by respondents as one of the main barriers to BIM adoption. A higher emphasis was placed on this cost factor by non-users than users, which indicates the possibility of overestimation of real operation costs by non-users. In addition, the results can provide an enriched understanding of the BIM adoption process in SMOs in Australia, which account for the largest proportion of the construction industry. The main limitation of this study is the relatively small sample size used at this stage. The future work involves recruiting more participants to improve the reliability of the findings.

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