Key Factors Affecting Construction Organizations' Acceptance of BIM: A Comparative Study

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ABSTRACT
Governments and clients expect contractors to utilise BIM for construction and maintenance purposes at higher level of details. However, the process of BIM implementation is not as quick as it was expected and looks some contractors have not used BIM at all, or do not use it for some of projects. This justifies an urgent study on the process of BIM adoption to identify drivers and key factors influencing the contractors' decision. Many studies focus on exploring BIM advances, its applications and individual matters of BIM acceptance. However, less effort has been made to investigate the impacts of organizations' intention considering BIM performance value and their support for BIM implementation. Therefore, this study aims to identify factors that affect the BIM adoption process at the organization level regarding perceived needs, organizational support and ease of operation. Quantitative and qualitative information are collected through survey and face-to-face interview in Chinese and Australian construction organizations. Structural equation modelling analysis is used to quantify the relationships between influential factors and organization's intention towards BIM utilization. Analysis results indicate that 'BIM Awareness', 'Perceived Needs', 'Organizational Support', and 'Down Time' are four critical factors influencing BIM acceptance in Chinese and Australian construction organizations. Moreover, this study provides an insight of BIM adoption challenges in Chinese and Australian construction industries.

KEYWORDS
BIM adoption; Influential factors; China; Australia; Construction organizations; Operation and Maintenance.

INTRODUCTION
Building Information Modelling (BIM) has been advocated as the development and use of a computer software model to simulate the construction and operation of a facility by Associated General Contractor of American (2006). The Australasian Chapter of buildingSMART indicates that the Australian economy could be better off by as much as $7.6 billion over the next decade by adopting BIM (Australasia, 2012). By realizing the vast amount of financial savings brought by BIM implementation, governments set their goals and scheduled their plans in pushing the

spread of BIM utilization. In Australia, it is recommended not mandated to use BIM in construction projects (BEIIC, 2012). Ministry of Housing and Urban-Rural Development of China aimed to achieve the digitalization goal within construction organizations in the 12th National Five-Year Plan (Jin et al., 2015). Advantages of using BIM also include shortening project duration (Azhar, 2011), improve product quality (Mutai, 2009), more efficient working processes (Aranda-Mena et al., 2009), and improved project team collaboration (Newton and Chileshe, 2012). Previous studies mainly focus on the development of BIM and its potential applications i.e. assessing energy performance in the early design stage (Schlueter and Thesseling, 2009), and estimating costs of the post-earthquake rehabilitation buildings (Charalambos et al., 2014). However, fewer papers attempt to investigate key factors associating with BIM adoption at the organizational level at different countries. Since BIM adoption gets affected from organizations' mission, industries' policies, and governments' guidance, it is important to explore similarities and differences of BIM adoption in different contexts. Table 1 describes the BIM utilization status in the various countries. For example, it proves that BIM adoption rate in U.K. is relatively higher than other regions. Therefore, this study aims to quantify and qualify the relationships between influential factors and organizational intention to use BIM, by using structural equation modelling analysis. This paper mainly consists of three parts; first part involves with influential factors' identification and model development; the second part focuses on analysing built structural equation models; the third part discusses similarities and differences between BIM adoption in Australia and China.

Table 1 BIM utilization status in various regions

Resources	Region	BIM utilization status
Allen Consulting Group (2010)	Australian	75% Australian engineering and construction contractors are BIM users. 84% contractors estimated that more than 30% of current projects use BIM, while only 73% of architectural organizations and 41% in engineering organizations.
McGrow Hills Construction (2012)	Australian Infrastructure Industry	47% A/E organizations have over 25% of projects involve with BIM in 2011, while the number of contractors is 43%.
Shenzhen Exploration & Design Association (2013)	Chinese Architectural & Engineering Industry	Over 90% of in entire 30 design organizations had heard of BIM, but 54% of them claimed that BIM application stayed in the experimental stage in small-size projects.
China Construction Industry Association (2013)	Chinese Construction Industry	In 2012, less than 15% of in total 388 Chinese contractors indicated that they had adopted BIM, although 55% of them stated that they had heard of BIM.

THEORISING BIM ADOPTION PROCESS

The literature provided a series of factors influencing BIM adoption. However, most of them are related to individual perception, and some others cover specific contexts and countries. This section revises the current literature to identify key factors may influence an organisation decision to use BIM in their projects. For example, Ding et al. (2015) targets on identifying key factors influencing BIM adoption to larger Chinese architectural firms. This study does not cover contractors, and the results show that adoption motivations, technical defects of BIM, and BIM capability may affect architects decision to accept BIM. Lee et al. (2013) identifies factors that influence BIM adoption in Korean construction organizations. This paper indicates that perceived usefulness influences organizational intention while the models based on individual perceptions and theories. Xu et al. (2014) explores the external factors which influence AEC organizations' intention to use BIM. Results indicate that factors like interoperability and willingness to learn BIM affect BIM adoption through Perceived Usefulness and Perceived Ease of Use. Sexton and Barrett (2003) notices that the implementation of innovation is a cyclical process from the diagnosis of innovation to execute detailed implementation plan, and eventually evaluate working performance after implementation. Therefore, this study identifies influential factors model throughout BIM implementation lifecycle. In order to formulate the BIM adoption model to quantify relationships between influential factors and organizational intention to use BIM, the most recommended factors in the literature are reviewed as follows and Table 2 presents detailed definitions and hypothesises.

Table 2 Variables and Definitions

Variable	Definitions & References	Hypothesises
Organizational Support (OS)	An individual receives supports from management level when using BIM (Lee et al., 2013).	H1: Organizational Support has a positive effect on Organizational' Intention to Use BIM (OI).
BIM Awareness (AW)	Technology awareness refers to users' knowledge about the capabilities of technology (Rogers, 1995).	H2a: AW has a positive effect on Organizational Support. H2b: AW has a positive effect on OI.
Perceived Needs (PN)	Perceived Needs refers to an organization feels the need to adopt BIM (Rogers, 2003) (Thompson et al., 1991).	H3a: PN has a positive effect on Organizational' Support. H3b: PN has a positive effect on OI.
Perceived Usefulness (PU)	Perceived Usefulness refers to the degree to which an individual belief that using a system would enhance his/her working performance (Davis, 1989).	H4a: PU has a positive effect on Organizational' Support. H4b: PU has a positive effect on OI.
Ease of Operation (EO)	The degree to which a person believes that using a particular system would be free of effort (Davis, 1989).	H5a: Organizational' Support has a positive effect on EO. H5b: EO has a positive effect on OI.
Ease of Maintenance (EM)	Ease of Maintenance refers to the degree to which an organization believes that maintaining BIM would be free of effort (Davis, 1989).	H6a: Organizational' Support has a positive effect on EM. H6b: EM has a positive effect on OI.
Down Time (DT)	A period that a system fails to provide or perform its primary function either planned or unplanned (Solutions, 2007).	H7a: Organizational' Support has a positive effect on DT. H7b: DT has positive effects on OI.

RESEACH METHOD

This study employed face-to-face interview approach to collect data from professionals of two different countries Australia and China. The close end questions were designed including 43 questions. Each question should be answered by a number ranged from 1 to 7 (1=strongly disagree to 7=strongly agree). Since two different countries were chosen the questionnaire were prepared in two languages English and Chinese. The survey recruited a total of 161 participants 77 from Australia and 84 from China. Respondents' profiles present in Table 3. The Structural Equation Modelling analysis was employed to validate the proposed BIM adoption model. SEM analysis allows researchers to assess the reliability of manifest factors and estimate the relationships among latent factors (Barclay et al., 1995). This study built two structural equation models in the different cultural backgrounds. As Anderson and Gerbing (1988) suggested using a two-step approach to reducing the potential model misspecification. Thus, in the first step, we modify models, removing few manifest factors with poor loading (Fornell and Larcker, 1981) (Bagozzi and Yi, 1988). The second phase is testing hypotheses and quantifying relationships between latent factors based on the modified model (Alwin and Hauser, 1975).

Table 3 Respondents' Profile

Item		China (%)	Australia (%)
Respondent Industry Background	Residential	35.71	41.08
	Commercial	32.14	38.80
	Infrastructure	32.14	20.12
Length of Using BIM	Non-users	30.95	31.17
	<12 months	13.09	12.98
	1-2 years	26.19	36.36
	2-5 years	27.38	15.58
	> 5 years	2.38	3.90
Most Frequently Used BIM Applications	Quantity take-off	75.86	54.55
	Clash detection	70.69	49.35
	3D visualization	63.79	75.32
	Cost estimation and cost planning	55.17	49.35
Average percent of projects involve with BIM		21	35
Average working experience		10 years	13.4 years

MODEL VALIDATION

Table 4 presents differences between Chinese construction organizations and Australian construction organizations, regarding organizations' sizes and project delivery method.

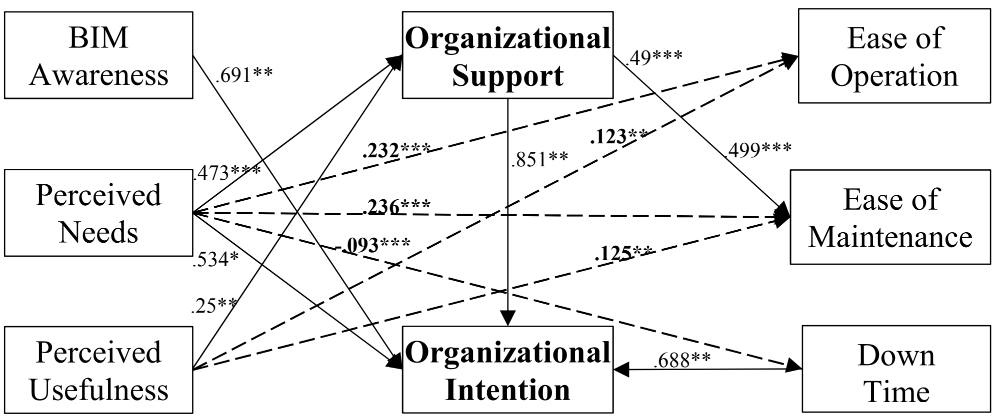
Table 4 Differences between Chinese and Australian respondents

	China	Australia
Majority of number of employees	> 1000	20 – 199
Average rank of 'clients are pushing to use BIM'	4.80/7	4.46/7
Average rank of 'understanding of BIM'	5.24/7	4.47/7
Average rank of 'organization provides BIM training'	5.01/7	4.03/7
Average rank of 'BIM learning process doesn't require strong computer background'	3.03/7	3.80/7

Note: 1=strongly disagree with the statement, 7=strongly agree with the statement

Analysis country by country

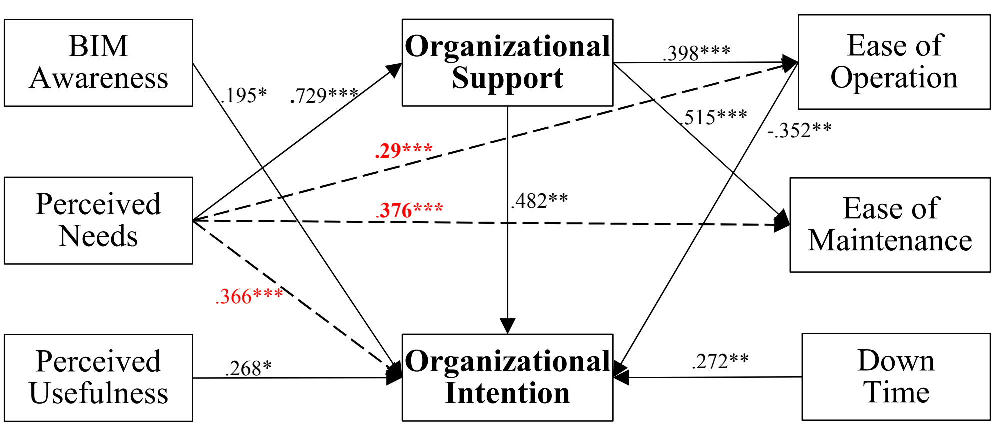
While analysis results of Australian construction organizations are more complicated. 'BIM Awareness', 'Perceived Needs', 'Organizational Support' and 'Down Time' are four essential factors affecting Australian construction organizations' intention to use BIM. Figure 1 presents significance and strength of effects. There are more indirect implications in the BIM adoption model based on Australian construction organizations, i.e. 'Perceived Needs to Ease of Operation', 'Perceived Usefulness to Ease of Maintenance'.



Note: p<0.1, **p<0.05, ***p<0.01

Figure 1 BIM adoption model in AUS

Analysis results under Chinese construction background indicated eight out of thirteen hypothesizes significant. Meanwhile, there are also indirect effects from Perceived Needs to Ease of Operation, Ease of Maintenances, and Organizational Intention. Figure 2 presents significance and strength of effects. 'BIM Awareness,' 'Perceived Needs,' 'Perceived Usefulness,' 'Organizational Support,' 'Ease of Operation', and 'Down Time' are identified as important factors to BIM adoption decision making among Chinese construction organizations.



Note: p<0.1, **p<0.05, ***p<0.01

Figure 2 BIM adoption model in CHN

DISCUSSION

This study aims to identify factors influencing an organisation decision to use BIM, which is the basis of modelling BIM adoption process. This study is different than current publications in three ways: 1) the analysis unit is organisation while many publications analysed the individuals' perceptions of BIM. 2) This study investigated new factors such as ease of operation and maintenance and down time when the previous studies mainly focused on ease of operation and awareness. 3) This paper also compares the process of BIM adoption in two totally different contexts to provide insight into BIM adoption from different perspectives. Both China and Australia are BIM advocates and intensively use new digital technologies and also they have collaboration in different construction projects, so they need the same communication channel in terms of exchanging drawings and 3D models. These will be discussed in the following sections separately:

According to SEM analysis results, 'BIM Awareness', 'Perceived Needs', 'Organizational support', and 'Down Time' are four essential factors to an organization's intention to use BIM. Within contrast to Chinese data set, 'Ease of Operation' has less effect on organizations' intention. According to Australian respondents, contractors tend to build a long-term partnership with architectural firms. However, contractors focus on their own communication ways which are dominate and take less responsibility for BIM utilisation. Meanwhile participates also discussed that young graduates who are working in the Australian construction industry have a high level of BIM knowledge and skills, and this facilitates BIM adoption process. This is in line with previous studies such as (Miller et al., 2013). Surprisingly, the first data set (e.g. Australia) does not support 'Perceived Usefulness' as a key factor as it doesn't have strong effect on organizations' intention. This finding is different than previous studies (Lee et al., 2013, Howard et al.). The reason is that perceived usefulness is originally recommended by Davis (1989) to measure individual perception and it cannot be applicable for organisations, unless we modify the definition of the factor in the future study. In addition, Lee et al. (2013) investigates the BIM acceptance among BIM users, while the focus of the current study is broader.

The second SEM analysis was done based on Chinese data set. The result of SEM shows that all six factors BIM Awareness,' 'Perceived Needs,' 'Perceived Usefulness,' 'Organizational Support,' 'Ease of Operation', and 'Down Time' factors affect Organizations' Intention to use BIM. The results also echo the previous finding as it shows awareness, perceived needs, usefulness and organizational support are necessary for BIM adopters. Ding et al. (2015) found that management support is critical to BIM adoption. Meanwhile, Xu et al. (2014) concluded that interests in learning BIM, perceived usefulness, and management support impact BIM adoption significantly. Although 'Ease of Operation' and 'Down Time' are crucial to organizations' intention to use BIM, 'Ease of Maintenance' is not considered as a major factor in an organization's decision of BIM adoption. Further discussion with participants also shows that most of the BIM authorized software in the current Chinese market are exotic software, instead of local software (Research, 2013). However, exotic software is incompatible with Chinese construction projects regarding project delivery and interoperability with other software (Association, 2013, Cao et al., 2015). Moreover, it is found that 'Perceived Needs' affect Organizations' Intention to Use BIM through influencing 'Organizational Support'. The study of Cao et al. (2015) also found that Chinese contractors often have internal incentives to implement innovation technologies (i.e. BIM) actively, due to the competitive building and construction markets.

CONCLUSION

This study aims at identifying key factors that influence the BIM adoption decisions in Chinese and Australian construction organizations. SEM analysis results indicate that 'BIM Awareness', 'Perceived Needs', 'Organizational Support', and 'Down Time' are four critical factors influencing BIM acceptance in both Chinese and Australian construction organizations. The results of this study also contribute to the body of knowledge by examining key factors (e.g. organizational support and perceived needs) influencing construction organizations' decision in the BIM adoption process, rather than focusing on factors (e.g. playfulness and complexity) related to the individual's perception of information systems usage. Although Australian and Chinese policies are not mandating BIM adoption in construction projects, external pushes from fierce competitive market motivate contractors to implement BIM. Also, the results can provide an enriched understanding of the BIM adoption process in construction organizations in Australia and China. Though we targeted research participants in each country after comparing BIM adoption rate and BIM implementation level, there are still differences regarding project sizes, organizations' size, and project delivery which needs to investigate deeper. Moreover, the BIM adoption model in Australian construction industry needs to modify.

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