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Critical Barriers to BIM Implementation in the AEC Industry

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Abstract

Building Information Modelling (BIM) is one of the most significant technological advances in the building design and construction industry to date. Implementation of BIM has increased significantly over the past decade; and it enables the different stakeholders of a construction project to collaborate better throughout its lifecycle, and improves the opportunities to share data and decrease consumption. However, the implementation of BIM lags far behind its potential due to the existence of various barriers. This paper aims at identifying, classifying, and prioritising these barriers to BIM implementation through a survey. The research findings are expected to assist major stakeholders in the construction industry to promote BIM implementation.

Keywords: building information modelling, barriers, implementation

1. Introduction

Building Information Modelling (BIM) is one of the most significant technological advances in the building design and construction industry. It has been attracting the attention of the global architecture, engineering, and construction (AEC) industry. The BIM concept can be traced back to the 1960s for the earliest computing applications, and to the 1970s for the emergence of solid modelling programs (Smith, 2014). The development of the ArchiCAD software is regarded as the real beginning of BIM and the application of the Revit software witnessed a switch to effective BIM implementation (Bergin, 2012). BIM was initiated to present the building process of a construction project virtually before building it physically, in order to figure out potential problems, and to simulate and analyse influences. BIM is not a simple application of CAD and 3D techniques. It is a system of organizing the right people and information together effectively and efficiently, while giving support to them with certain defined processes and technology. The highlights of BIM are people, information, processes, and technology (RICS, 2014).

BIM is a 3D-object database that can be easily visualized, and that contains rich data and structured information. Furthermore, BIM can be applied to the analysis of building performance, sustainability, schedules, and costs (Uddin and Khanzode, 2013). BIM was initially applied to the construction stage of building projects, but it now encompasses the operation and maintenance stages, and also infrastructure such as bridges and stadiums. BIM has established a set of maturing technologies, and a process of representing buildings and infrastructure over their whole lifecycles (Demian & Walters, 2014).

BIM has reinvented the AEC industry over the past two decades. The concept of BIM has expanded from 3D modelling to 4D programming linked with the construction process, 5D modelling integrated with cost data, and even nD modelling. It is widely believed that BIM can play a significant role in integrating the various stages throughout the entire lifecycle of a construction project (Jung & Joo, 2011). The first wave of BIM implementation struck the AEC industry from the middle 1990s, as a way to overcome low construction productivity and other barriers hampering innovation in the industry (Teicholz, 2004). BIM technology provides a range of direct and indirect benefits, and has made the entire design and construction process more simplified and transparent in many aspects (Lee et al., 2012).

It is estimated that BIM can eliminate unbudgeted change by 40%, and reduce the time to complete a project by 7%, and the time to generate a cost estimate by up to 80% (Azhar, 2011). The use of BIM can integrate design, construction, maintenance, and demolition data about building into a rich model, and assist all stakeholders with improvements in performance efficiency, and reduction of costs, risk, and waste, as well carbon emissions.

Buildings can be constructed more quickly and precisely through automated assembly and enhanced processes which dramatically decrease construction errors and conflicts, and improve construction quality and efficiency. BIM provides a practical solution to reducing carbon emissions, as technology innovation drives sustainable building design, construction, and operation. BIM technology also leads to labour market improvements, encourages more collaborative working practices, and improves communication between project stakeholders (Allen Consulting Group, 2010).

The success of technology implementation depends on many factors. For example, personnel's attitudes toward new technology implementation are shaped by the risks involved in using unknown means and methods, the difficulty of implementing new technology, financial risks, and the perception of other workers' attitudes toward new technologies (Tatum, 1989). As a new technology in the construction industry, while BIM is expected to deliver many benefits to the industry, a range of barriers have hampered its widespread implementation.

2. Barriers to BIM Implementation

2.1 Classification of Barriers

BIM implementation in the construction industry has been restricted by many barriers, which can be categorised into five major groups: lack of a national standard; the high cost of application; the lack of skilled personnel; organizational issues; and legal issues. Each barrier can then be divided into two or three sub-groups, as shown in Table 1. Its rightmost column enumerates several typical pieces of literature discussing these barriers. Each category will be explained in more details.

Table 1. Summary of barriers in BIM implementation

Category	Item	Literature
Lack of national standard	Incomplete national standard Lack of information sharing in BIM	Bernstein & Pittman, 2004; Thomson & Miner, 2006; Björk & Laakso, 2010; Azhar, 2011; Aibinu & Venkatesh, 2014; Alreshidi et al., 2014
High cost of application	High initial cost of software High cost of implementation process	Allen Consulting Group, 2010; Thomson & Miner, 2010; Azhar, 2011; Ganah & John, 2014
Lack of skilled personnel	Lack of professionals High cost of training and education	Smith & Tardif, 2009; Allen Consulting Group, 2010; Sharag-Eldin & Nawari, 2010; Becerik-Gerber et al., 2011; NATSPEC, 2013 ; Wu & Issa, 2014
Organizational issues	Process problems Learning curve Lack of senior support	Arayici et al., 2011; Won et al., 2013; Aibinu & Venkatesh, 2014; Demian & Walters, 2014
Legal issues	Ownership Responsibility for inaccuracies Licensing problems	Thomson & Miner, 2006; Chynoweth et al., 2007; Azhar, 2011; Udom, 2012

The development of a national strategy for BIM implementation would set out national priorities and provide guidance across the whole industry. It is necessary to standardize the BIM process and publish guidelines for its implementation (Azhar, 2011; Thomson & Miner, 2006). Furthermore, there is a need for well-developed practical strategies classifying the industry's types of work (Bernstein & Pittman, 2004). However, there is no clear general agreement regarding BIM implementation and use. Some building guidelines have been developed, but no formal standard exists to organize industry practice. Standards are common throughout the AEC industry (Björk and Laakso, 2010), but BIM implementation requires the development of new standards. The lack of a national standard for sharing data between all stakeholders in the implementation process is seen as a barrier (Allen Consulting Group, 2010).

Data inconsistency is the most prominent data-related issue, and data compatibility for sharing or exchange is the second most common (Alreshidi et al., 2014). Willingness to share information among project stakeholders is considered critical. This means BIM should include the capability to transmit and reuse the information embedded in the graphical mode, and therefore a lack of information sharing could constitute a barrier to BIM implementation (Aibinu & Venkatesh, 2014).

While BIM is expected to provide significant benefits to the AEC industry, its implementation requires costs, as with any new technology. The perceived costs of implementing BIM technology include education and training costs, administration and start-up costs, and transition and behavioural costs. The cost of implementation is frequently recognized as a barrier to BIM implementation. The increase in the implementation of BIM in the industry is mainly within large companies which have the resources (Ganah & John, 2014). BIM implementation requires specific software and data storage, which mean a significant cost to a company. The cost of purchasing new software depends on the firm's existing IT facility, while that cost could present a barrier to small firms. This issue of cost forces investors and potential BIM adopters to consider the options carefully (Allen Consulting Group, 2010).

Education and training costs have two broad elements: ensuring a company has the required personnel, either by hiring new staff or retraining existing staff, to establish and integrate BIM technology into its operations; and retraining the majority of existing staff to support the behavioural and organizational changes required to fully adopt BIM technology within a business model (Allen Consulting Group, 2010). Studies have shown that BIM education can significantly enhance students' competitiveness in today's job market (Wu & Issa, 2014). Presently the AEC industry continues to inform its associated members and stakeholders about BIM implementation in a variety of ways. The core of BIM evolution is education and training (Sharag-Eldin & Nawari, 2010), which is considered to be a solution that can accelerate the BIM learning curve. It seems that post-secondary BIM education outcomes have yet to meet the expectations of the industry. Most BIM education and training available to date focus on the use of particular BIM software packages, with less attention to practical applications (NATSPEC, 2013). The lack of adequately trained BIM professionals has hindered BIM implementation and use in the AEC industry (Becerik-Gerber et al., 2011). This gap in skills is a barrier to further BIM implementation. This situation is likely to become worse due to a persistent shortage of capable BIM professionals over the next 20 years (Smith & Tardif, 2009).

The organizational issues with BIM implementation include professional liability, process problems, and trust (Won et al., 2013). The collaborative work managed by BIM emphasises the problem of interoperability (Demian and Walters, 2014). Senior managers are reluctant to introduce new technologies and processes to the organization, while management support for BIM implementation is essential (Ruikar et al., 2005). A bottom-up approach is considered more efficient in dealing with resistance to change (Arayici et al., 2011). Some managers are concerned that the learning curve required with BIM could affect their business, and the lack of knowledge about what needs to be done to progress from traditional work is clearly identified as a barrier to BIM implementation (Aibinu & Venkatesh, 2014).

Addressing the legal aspects of BIM development is also necessary. The first legal risk is related to the ownership of BIM data. If owners pay for the architectural design of construction projects, they may claim ownership of the design documentation. Licensing problems may arise when other stakeholders than the owners and architects contribute data that is integrated into BIM (Azhar, 2011). Another issue is how to determine who will control the access to data, and be responsible for inaccuracies; and this aspect could bring about a great deal of risk (Thomson & Miner, 2006). Stakeholders require security of confidential data in the BIM model, but a range of legal and security issues have been identified in connection with the administration of construction projects within an electronic environment (Chynoweth et al., 2007; Udom, 2012).

2.2 Hypotheses on Critical Barriers to BIM Implementation

The above-identified barriers to BIM implementation influence each other. Figure 1 shows the links between BIM implementation and the five categories of barriers. BIM implementation is not just a technical issue, and has effects on organizational structure and work processes in various companies in the AEC industry. This type of change brings organizational issues. When BIM implementation is related to external parties beyond the enterprise, such as suppliers, economic and legal issues will be involved. BIM implementation dramatically reduces the costs of construction projects from the beginning (Allen Consulting Group, 2010). The initial high cost of BIM software requires changes in enterprise organization or workflow, raising organizational issues, while the high cost of human resources directly leads to the lack of professionals. Incomplete standards produce information-sharing and data-sharing conflicts, which raise legal issues about ownership of and access to the data. Simultaneously, the lack of a national standard means there is no unified personnel training level, increasing the personnel shortage.

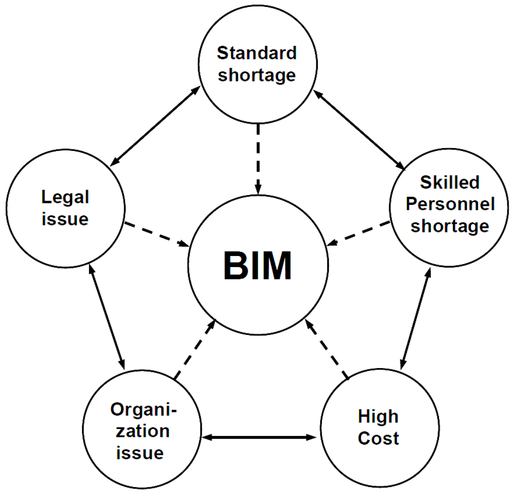

Figure 1. Relationship between main barriers

Due to the complexity of factors affecting organizational and legal barriers, this paper only investigates the lack of a national standard, the high costs and the shortage of skilled personnel for BIM implementation. With investigation of the degree and nature of public attention to the main barriers to BIM implementation, this research proposes some recommendations to overcome these barriers. In order to achieve these objectives, two research hypotheses are proposed:

H1: A national strategy is necessary in order to implement BIM in the AEC industry.

H2: Cost is recognised as the biggest barrier in BIM implementation.

3. Research Design

Previous research has indicated that the response rate of a data survey drops significantly with an increase in the number of survey questions (PeoplePulse, 2005). In order to get a valuable answer from every respondent, the survey questionnaire applied in this research consisted of just four questions, which are presented in Table 2. Except for Question 3, which allowed survey participants to select their top three choices, the other three questions asked for only one choice. The first two questions investigate respondents' recognition of the necessity of BIM implementation and national strategies. Question 3 is the core of the questionnaire and investigates respondents' level of attention to the main barriers to BIM implementation. The last question was designed to discover respondents' expectations of the government role in BIM implementation based on the barriers.

Table 2. Questionnaire questions

No.	Questions
1	How important do you think BIM use is for more effective architecture, engineering and construction (AEC) companies? □ Very important □ Important □ Not important
2	Are you aware of the national strategies associated with BIM in your country? If no, do you know others? □ Yes □ No (any country) □ Other countries
3	What are the main barriers of BIM implementation? □ Incomplete national standard □ Lack of information sharing in BIM □ High initial cost of software □ High cost of implementation process □ Lack of professionals □ High cost of training and education
4	What roles should the government play in promoting BIM implementation? □ Leading role □ Guiding role □ General role □ Not involved

Group meetings were used to collect the survey data in this research. Survey sampling requires the selection of a small sub-population that is representative of the entire population. For this research, samples from four distinct populations associated with BIM implementation were selected: academic staff; students in universities; industrial BIM applicants; and government officials related to architecture, engineering, and construction management disciplines. Among the groups, academics concentrated on theory research of BIM technology while students were learner of the research as well the potential user. Industrial applicants perceived the barriers most directly while government could make efforts to overcome the barriers. The questionnaires were sent to all respondents by email ahead of the group meetings, together with a plain language explanation of the research purpose.

A number of group meetings were held in China and Australia from the end of 2014 to early 2015. In total, 64 valid questionnaires were received. Among them, 27 respondents were from Australia and 37 were from China, including 14 from industry, 10 government employees, 16 academic staff, and 24 undergraduate and postgraduate university students.

4. Data Analysis

4.1 Importance of BIM Implementation in the Industry as a National Strategy

The importance of BIM implementation in the AEC industry (Hypothesis 1) was first examined through Questions 1 and 2. Question 1 had three possible responses: 'very important,' 'important' and 'not important.' Sixty of the 64 respondents believed that BIM application plays a significant role, among which a majority of the respondents considered that BIM application for companies is very important in order to enhance quality. These results indicate that BIM implementation in the AEC industry has attracted widespread attention and BIM implementation has been recognized as a core element of the design process based on 3D modelling.

A national strategy is a vital factor in promoting BIM implementation. Figure 2 is a description of respondents' views about a national strategy. All government staff and university staff were aware of national strategies for BIM implementation in their own countries, while some industry staff and university students were not aware of BIM implementation strategies in any countries. Government employees showed much more concern in relation to BIM for their own national strategies, rather than focusing on other countries. Professional BIM applicants in the industry had low awareness of BIM implementation strategies both domestically and internationally. University staff not only had a high degree of awareness of domestic standards and strategies relative to BIM, but also paid relatively balanced attention to a number of other countries. They teach the international forefront of BIM theory and practical skills to students, and so they need to gain a certain degree of understanding of the global status of BIM application. It is surprising that a high proportion of Australian students had no idea about any national standards. This reflects the fact that they have been taught little about BIM implementation throughout their university course. Overall, the results show that national standards and strategies do receive attention in the AEC industry.

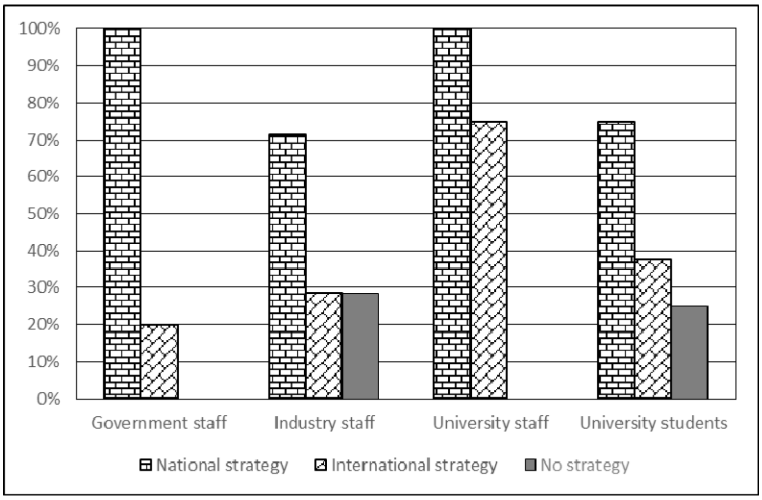

Figure 2. Awareness of national strategy

The results indicate that the respondents who selected 'very important' in Question 1 were all aware of their own national strategies in relation to BIM. The same is true of most respondents who chose 'important' in Question 1. Those respondents who thought BIM implementation is not important did not know about national standards and strategies. Perhaps they were not involved in the BIM implementation process, or BIM was not associated with their own work. Therefore, BIM implementation in the industry as a national strategy is highly necessary according to the results of this survey.

4.2 Priority of Attention to Barriers to BIM Implementation

In Question 3, six possible barriers were provided for the respondents to prioritise three key factors: Incomplete national standard (A1); Lack of information sharing in BIM (A2); High initial cost of software (B1); High cost of implementation process (B2); Lack of professionals (C1); and High cost of training and education (C2). Figure 3 presents the results about the level of attention to the barriers. The top three choices of the respondents are: B1 High initial cost of software; A1 Incomplete national standard; and C1 Lack of professionals, which account for 70.31%, 68.75%, and 60.94% of the total number of respondents respectively. The other three barriers are: B2 High cost of implementation process 40.63%; C2 High cost of training and education 39.06%; and A2 Lack of information sharing in BIM 20.31%. Except for the university staff, the other three groups of respondents chose B1 High initial cost of software as the most significant barrier to BIM implementation. This may indicate that they were most concerned about the acquisition cost of software for BIM implementation. A1 Incomplete national standard was the dominant barrier for the university staff, and they did not think that C1 Lack of professionals is as undeveloped as the other three groups did.

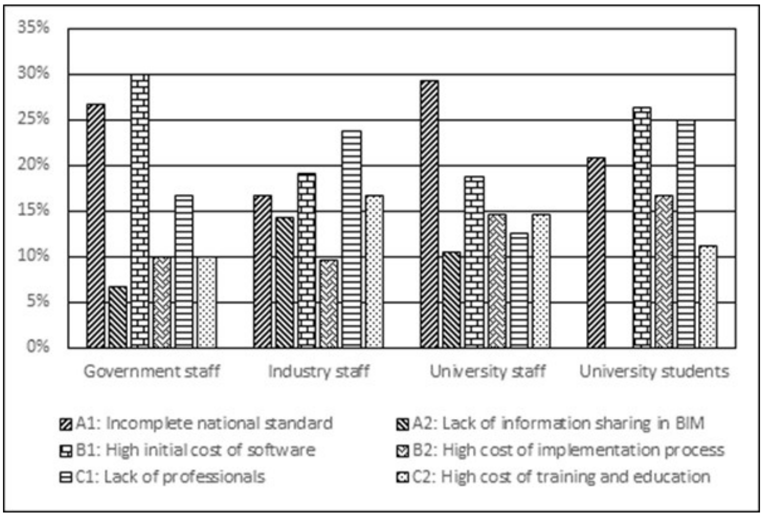

Figure 3. Recognition of main barriers in BIM implementation

The top three barriers selected by the university students are similar to those of the other three groups. However, no students considered A2 Lack of information sharing in BIM as a barrier. This may indicate that the university students had not yet become aware of the importance and difficulties of information sharing for BIM implementation in practice and had gained limited knowledge from teaching and practice, and so BIM techniques and its applications should be offered in more depth in their university courses.

Figure 4 displays the most preferred single choice among the barriers. The top three are consistent with the statistics of the total respondents' sample. A1 Incomplete national standard accounts for 34.38% of the total respondents' preferences, in particular 70.00% of the government staff. The university students considered B1 High initial cost of software the top barrier, but the other groups did not consider it a dominant issue. Interestingly, the university staff believed that C2 High cost of training and education implicated BIM implementation in the industry more than the other five factors. None of the government staff, industry staff, or university students considered A2 Lack of information sharing in BIM as the greatest barrier, and it was also selected by few university staff. No government staff chose B2 High cost of implementation process as the most significant barrier.

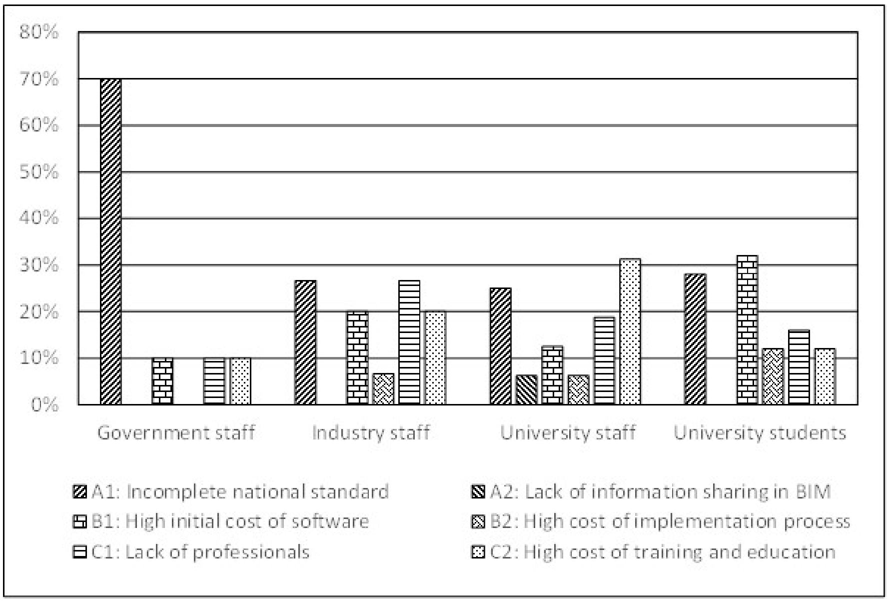

Figure 4. First single choice of barriers

A scale table which was similar to Likert Scale was applied in order to deliver a more significant results of the attention degrees. The respondents' top three options among these six items are listed as key factors (KFs) and were given scores of 5, 4 and 3 according to their rank. Others not ranked are regarded as less key factors (SKFs) with a score of 1. Table 3 summarises the ranks of the barriers and their scores.

Table 3. Single item weighting scores

No.	Factors	Rank	Importance	Assessment points
1		1	Very important	5
2	Key factors	2	Important	4
3		3	Less important	3
4	Secondary key factor	Not ranked	Not important	1

According to the weighted scores given in Table 3, a comprehensive score was calculated for each barrier in consideration of the numbers of respondents in each of the four groups and is shown in Table 4. The greatest category among the barriers to BIM implementation is the high cost of application (category B) with a score of 337; the lack of skilled personnel (category C) is ranked second with a score of 325, and the lowest is the lack of a national standard (category A) with a score of 302. In summary, this preliminary survey of BIM implementation barriers supports Hypothesis 2. Respondents had a shared understanding of the barriers to BIM implementation: that high costs are the greatest one.

The Australian respondents focused on 'Incomplete national standard', 'High cost of training and education', 'High cost of implementation process', and 'Lack of professionals'. Although Australia has established its own BIM standards, the standardization of information in the Australian AEC industry in relation to the deep promotion of BIM needs further improvement. Due to the high cost of education and training in Australia, the number of BIM professionals has been affected. The impact of the cost of BIM implementation has exceeded that of purchasing the software, and it has become one of the main barriers.

The Chinese respondents focused on 'High initial cost of software', 'Incomplete national standard', and 'Lack of professionals'. The BIM software used in China's AEC industry is mostly provided by foreign suppliers (especially the basic 3D software). The Chinese AEC industry is in an early stage of promotion of BIM implementation, and it is encountering the difficulty that purchasing foreign software requires an amount of capital. China has not published a formal national BIM standard, and the shortage of professionals in China is another main barrier to BIM implementation.

Table 4. Summary of weighted scores of barrier attention in BIM implementation

Item	Level	Government staff		Industry staff		University staff		University students		Subtotal	Total
		amount	score	amount	score	amount	score	amount	score	score	score
A1	1	7	35	4	20	4	20	7	35	*206*	*302*
	2	0	0	1	4	5	20	4	16		
	3	1	3	2	6	5	15	4	12		
	Other	2	2	7	7	2	2	9	9		
A2	1	0	0	0	0	1	5	0	0	*96*	
	2	0	0	1	4	3	12	0	0		
	3	2	6	5	15	1	3	0	0		
	Other	8	8	8	8	11	11	24	24		
B1	1	1	5	3	15	2	10	8	40	*202*	*357*
	2	8	32	4	16	3	12	5	20		
	3	0	0	1	3	4	12	6	18		
	Other	1	1	6	6	7	7	5	5		
B2	1	0	0	1	5	1	5	3	15	*135*	
	2	1	4	2	8	3	12	3	1		
	3	2	6	1	3	3	9	6	18		
	Other	7	7	10	10	9	9	12	12		
C1	1	1	5	4	20	3	15	4	20	*183*	*325*
	2	1	4	5	20	1	4	10	40		
	3	3	9	1	3	2	6	4	12		
	Other	5	5	4	4	10	10	6	6		
C2	1	1	5	3	15	5	25	3	15	*142*	
	2	0	0	1	4	1	4	2	8		
	3	2	6	3	9	1	3	3	9		
	Other	7	7	7	7	9	9	16	16		

4.3 Expectations of Government Role

The survey respondents had some expectations of government roles based on Hypothesis 1. In Question 4, to test the government factor more accurately, it was divided into 'leading role' and 'guiding role'. The survey results shown in Figure 5 indicate that 92.63% of respondents believed that governments should play a very important role in the BIM implementation process and give it due recognition, indicating that respondents had expectations of government support.

More than half of the respondents (51.6%) believed that governments should play a leading role, which means that governments should take full advantage of their administrative functions, and actively participate in the promotion process. A further 39.1% of the respondents believed that governments should play a guiding role, which means there is a need not to lead but to inspire the development of the industry. All government staff thought governments should take a leading or guiding role in BIM implementation. Few industry staff thought that governments should be not involved in BIM implementation at all.

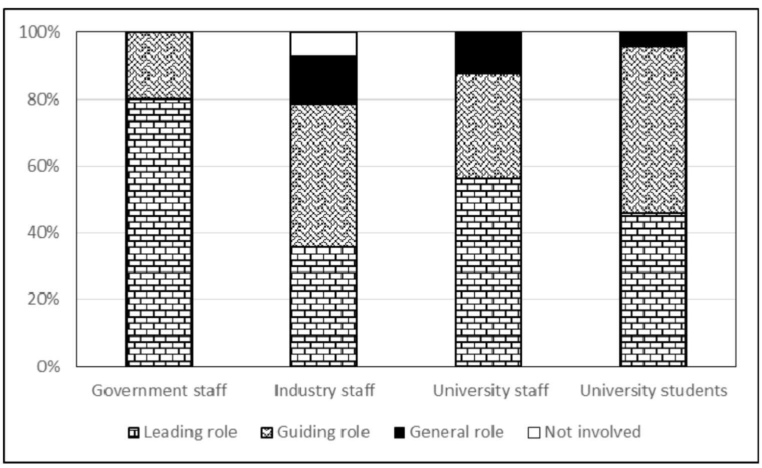

Figure 5. Expectations of government roles

5. Conclusions

The BIM concept and technology have been applied in practice worldwide, and the great effects brought about by BIM application in the AEC industry are gradually being revealed. BIM implementation is essential to the AEC industry, and support from a national strategy is necessary in order to promote BIM. Barriers to BIM implementation have attracted widespread attention. The critical barriers are the high cost of application, lack of national standards, and lack of skilled personnel. The four groups of survey participants had a common awareness of the critical barriers, and the cost is the greatest one. The initial cost of investing in new technology and time for training personnel is also significant. It is recommended that government, the AEC industry, educational institutes, and BIM providers work together to reduce BIM implementation costs, establish BIM implementation strategies, and promote BIM education. With investigation and overcoming of the identified barriers, BIM will help the AEC industry to evolve rapidly.

The small sample size in this research increased the uncertainty of the results. As degrees of regional economy and industry development had influence on respondents' choices, the findings may not be suitable or be generalized to other countries. The connections among answers of questions should be investigated and further research was also required to validate the actual barriers from the viewpoint of decision makers.

References

Aibinu, A., & Venkatesh, S. (2014). Status of BIM Adoption and the BIM Experience of Cost Consultants in Australia. *Journal of Professional Issues in Engineering Education and Practice, 140*(3). http://dx.doi.org/10.1061/(ASCE)EI.1943-5541.0000193

Allen Consulting Group. (2010). Productivity in the buildings network: assessing the impacts of Building Information Models, report to the Built Environment Innovation and Industry Council. Sydney.

Alreshidi, E., Mourshed, M., & Rezgui, Y. (2014). Exploring the Need for a BIM Governance Model: UK Construction Practitioners' Perceptions. *Computing in Civil and Building Engineering,* ASCE, 151-158. http://dx.doi.org/10.1061/9780784413616.020

Arayici, Y., Coates, P., Koskela, L., Kagioglou, M., Usher, C., & O'Reilly, K. (2011). Technology adoption in the BIM implementation for lean architectural practice. *Automation in Construction, 20*(2), 189-195. http://dx.doi.org/10.1016/j.autcon.2010.09.016

Azhar, S. (2011). Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry. *Leadership and Management in Engineering, 11*(3), 241-252. http://dx.doi.org/10.1061/(ASCE)LM.1943-5630.0000127

Becerik-Gerber, B., Gerber, D. J., & Ku, K. (2011). The pace of technological innovation in architecture, engineering, and construction education: integrating recent trends into the curricula. *Journal of Information Technology in Construction, 16*, 411-432.

Bergin, M. (2012). *A brief history of BIM*. Retrieved from http://bit.ly/1gG8lSj

Bernstein, P. G., & Pittman, J. H. (2004). Barriers to the Adoption of Building Information Modeling in the Building Industry. *Autodesk Bulding Solutions.*

Björk, B.-C., & Laakso, M. (2010). CAD standardisation in the construction industry—A process view. *Automation in Construction, 19*(4), 398-406. http://dx.doi.org/10.1016/j.autcon.2009.11.010

Chynoweth, P., Christensen, S., McNamara, J., & O'Shea, K. (2007). Legal and contracting issues in electronic project administration in the construction industry. *Structural Survey, 25*(3/4), 191-203. http://dx.doi.org/10.1108/02630800710772791

Demian, P., & Walters, D. (2014). The advantages of information management through building information modelling. *Construction Management and Economics, 32*(12), 1153-1165. http://dx.doi.org/10.1080/01446193.2013.777754

Ganah, A. A., & John, G. A. (2014). Achieving Level 2 BIM by 2016 in the UK. *Computing in Civil and Building Engineering,* ASCE, 143-150. http://dx.doi.org/10.1061/9780784413616.019

Jung, Y., & Joo, M. (2011). Building information modelling (BIM) framework for practical implementation. *Automation in Construction, 20*(2), 126-133. http://dx.doi.org/10.1016/j.autcon.2010.09.010

Lee, G., Park, H. K., & Won, J. (2012). D^3 City project—Economic impact of BIM-assisted design validation. *Automation in Construction, 22*, 577-586. http://dx.doi.org/10.1016/j.autcon.2011.12.003

NATSPEC. (2013). BIM Education-Global-Summary Report. Sydney, Australia.

PeoplePulse. (2005). *Survey Response Rates*. Retrieved from http://bit.ly/1U37f5l

RICS. (2014). *What is BIM*. Retrieved from http://bit.ly/1OG9RmM

Ruikar, K., Anumba, C., & Carrillo, P. (2005). End-user perspectives on use of project extranets in construction organisations. *Engineering, Construction and Architectural Management, 12*(3), 222-235. http://dx.doi.org/10.1108/09699980510600099

Sharag-Eldin, A., & Nawari, N. O. (2010). BIM in AEC Education. Structures Congress jointly with North American Steel Construction Conference in Orlando, Florida, 1676-1688. http://dx.doi.org/10.1061/41130(369)153

Smith, D. K., & Tardif, M. (2009). *Building information modeling: a strategic implementation guide for architects, engineers, constructors, and real estate asset managers*. John Wiley & Sons. http://dx.doi.org/10.1002/9780470432846

Smith, P. (2014). BIM Implementation – Global Strategies. *Procedia Engineering, 85*, 482-492. http://dx.doi.org/10.1016/j.proeng.2014.10.575

Tatum, C. (1989). Organizing to increase innovation in construction firms. *Journal of Construction Engineering and Management, 115*(4), 602-617. http://dx.doi.org/10.1061/(ASCE)0733-9364(1989)115:4(602)

Teicholz, P. (2004). Labor productivity declines in the construction industry: causes and remedies. *AECbytes Viewpoint* on April 14, 2004.

Thomson, D. B., & Miner, R. G. (2006). *Building Information Modeling – BIM: Contractual Risks are Changing with Technology*. Retrieved from http://bit.ly/1CXSvka

Uddin, M. M., & Khanzode, A. R. (2013). Examples of How Building Information Modeling Can Enhance Career Paths in Construction. *Practice Periodical on Structural Design and Construction, 19*(1), 95-102. http://dx.doi.org/10.1061/(ASCE)SC.1943-5576.0000171

Udom, K. (2012). *BIM: mapping out the legal issues*. Retrieved from http://bit.ly/1IoVbrd

Won, J., Lee, G., Dossick, C., & Messner, J. (2013). Where to focus for successful adoption of building information modeling within organizations. *Journal of Construction Engineering and Management, 139*(11). http://dx.doi.org/10.1061/(ASCE)CO.1943-7862.0000731

Wu, W., & Issa, R. R. A. (2014). BIM Education and Recruiting: Survey-Based Comparative Analysis of Issues, Perceptions, and Collaboration Opportunities. *Journal of Professional Issues in Engineering Education and Practice, 140*(2). http://dx.doi.org/10.1061/(ASCE)EI.1943-5541.0000186