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Barriers to BIM in the Chinese AEC Industry

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Barriers to BIM in the Chinese AEC Industry

Abstract

The Chinese AEC (architecture, engineering and construction) industry is one of the biggest and most important in the world, but also well known for its relatively low efficiency and profitability. Building information modeling (BIM) has been introduced as a concept to uplift the industry's efficiency and is becoming an increasingly popular and a major topic in China, with strong commitment by the government for the country's future national AEC development and mandatory adoption in some localities. However, its take up in China continues to be very slow. The reasons for this have received little systematic study to date. This paper describes a survey of 136 owners, designers and contractors aimed at systematically and comprehensively analyzing the barriers involved by examining and comparing the perceptions of these three stakeholder groups.

The results indicate that owners have limited understanding of BIM except for its 3D visualization and clash detection capabilities, designers are predominantly concerned with the uncertain amount of return of investment in the technology, and contractors are worried about having to change their mode of operation. The conflicting perceptions of BIM implementation barriers between the three groups arise mainly from three sources: the drive for adoption, traditional culture and talent cultivation. Specifically, key issues are the roles the government and the market should play in assisting the BIM adoption and the importance of government mandates and incentives given China's political, social, economic and cultural environment; the traditional Chinese culture of encouraging thinking/doing in a more ambiguous manner than is suited to BIM's emphasis on precision, with conventional management philosophy paying more attention to people than technical development; and the need for qualified BIM professionals capable of operating the software and managing construction as well as coordinating team members.

Keywords: BIM, AEC industry, China, barriers, stakeholder survey.

1. Introduction

The Chinese AEC (architecture, engineering and construction) industry is one of the biggest and most important markets around the world (Dodge Data & Analytics, 2015). However, its relatively low efficiency and profitability is a well-recognized problem and practitioners are urged to adopt innovative technologies and processes to improve the industry's overall performance. BIM (building information modeling) has been introduced as a concept to uplift the industry's efficiency. Through BIM, building information can be generated, stored, managed, exchanged and shared in an interoperable and reusable manner (Eadie *et al.*, 2013). With overseas experience demonstrating that great benefits can be obtained by the use of BIM in project delivery (e.g. fewer design coordination errors, more energy efficient design solutions, faster cost estimation, reduced production cycle times and lower construction costs)(Cao *et al.*, 2015), BIM is becoming an increasingly popular and a major topic in China.

Commitment is strong, with BIM technology being seen by the government as being crucial for national building industry development and with mandatory adoption in some localities. However, despite this and there being little doubt that BIM will bring a revolution to the industry, its take up in China continues to be very slow. The reasons for this have received little systematic study to date. In response, this study aims to systematically and comprehensively analyze the barriers to Chinese AEC industry BIM adoption by examining and comparing the perceptions of the three main stakeholder groups (owners, designers and contractors). The paper begins with a brief review of the history of BIM and its application in China. This is followed by an introduction to the research methodology and process. The survey results are then presented to uncover the consistency and differences in the concerns of the groups regarding the obstacles to BIM implementation in China together with the outcomes of a series of in-depth validation interviews. Concluding remarks summarize the main findings and consider the research agenda needed for the future.

2. Literature review

2.1 BIM history and concept

The concept of BIM, or building description systems more precisely, was first developed by Eastman (1976) in the mid-1970s as "*a database capable of describing buildings at a detail allowing design and construction*". The ideas involved, i.e. parametric design, deriving 2D drawings from a model, a "*single integrated database for visual and quantitative analyses*" are beneficial for contractors of large projects in terms of scheduling and materials ordering (Eastman, 1975). This method or approach was later described as "building product models" in the United States or "product information models" in Europe – both emphasizing "product" rather than "process" (Eastman *et al.*, 2011). The term "building modeling" – which is closer to the term "building information modeling" used today - was first documented in 1986, combining the concepts of 3D modeling, automatic drawing extraction, intelligent parametric components, relational databases, temporal phasing of construction processes, etc. (Aish, 1986).

BIM, as an ever-evolving area and frontier, is creeping into the boundaries of its concepts (RICS, 2014). Though difficult, many government departments of different countries and regions and studies worldwide have provided exemplary definitions of BIM, as summarized in Table 1.

<Insert Table 1>

A holistic definition of BIM should, therefore, encompass three interconnected aspects, namely: the model product (i.e. a structured dataset describing a building), modeling process (i.e. hardware and software used for creating a building information model), and model application (i.e. collaborative practices, standards, semantics, etc.) (Wong and Fan, 2013; RICS, 2014). The benefits of BIM are increasingly recognized by practitioners and academics, with its application providing up to 40% reduction in unbudgeted changes; cost estimation accuracy within 3% as compared to traditional estimates; up to 80% reduction in time taken to generate a cost estimate; savings of up to 10% of the contract value through clash detections; and up to 7% reduction in project time (Azhar, 2011).

The benefits of BIM also differ between different project stakeholder groups (McGraw Hill Construction, 2014a; 2014b). The most important three advantages of BIM engagement, as rated by contractors for example, comprise reduced errors and omissions, collaboration with owners / design firms and an enhanced organizational image (McGraw Hill Construction, 2014a). Owners, on the other hand, perceive visualization as the top BIM benefit since it enables the proposed design to be better understood (McGraw Hill Construction, 2014b). As a result, many researchers are advocating the application of BIM at all stages of the project life-cycle (Eadie *et al.*, 2013; Bryde *et al.*, 2013), with the Singapore Building and Construction Authority, for example, detailing the BIM key activities and objectives involved in each project phase of conceptual design, schematic/preliminary design, detailed design, construction, as-built and facility management (BCA, 2013).

2.2 BIM adoption in the Chinese AEC industry

The United States and Scandinavian region (i.e. Norway, Denmark and Finland) have long been the global leaders in BIM implementation in the AEC industry (Smith, 2014). China, however, is still in the infancy stage of BIM adoption. A very recent study conducted by Dodge Data & Analytics found that, nearly half (46%) of the architects and a third (31%) of the contractors in China are currently at the lowest level of BIM implementation (i.e. less than 15% of projects involving the use of BIM) (Dodge Data & Analytics, 2015). Nevertheless, the commitment of the AEC industry in China to adopt BIM is strong. This is partly attributed to the national / provincial requirements for innovation and development. As emphasized in the Ministry of Housing and Urban-Rural Development's 12th national 5-Year Plan, BIM technology is crucial for developing the national building industry in terms of industrialization, informatization, urbanization and agricultural modernization. In Guangdong province, BIM adoption is generally required for all projects with building area no less than 20,000 m^2 by the end of 2020 (Department of Housing and Urban-Rural Development of Guangdong Province, 2014). Although Chinese AEC industry practitioners have a powerful demand for BIM, both actively and passively, its implementation in the country is not easy. Various barriers have hindered BIM development to date and a thorough identification of these is a timely and valuable need for improving BIM practices and the effectiveness of the industry.

3. Research methodology and process

A combination of common construction management research methods was adopted in this study, comprising (i) literature review; (ii) interviews; and (iii) questionnaire survey to thoroughly and comprehensively collect data concerning BIM application both locally and outside China.

3.1 Literature Review

The global literature was carefully reviewed and analyzed through content analysis. As a result, the barriers to BIM application in the AEC Industry in different countries and regions identified as summarized in Table 2.

<Insert Table 2>

3.2 Interviews

The findings of the literature review served as the basis for compiling a list of barriers to BIM implementation on the international scale. Their applicability in the Chinese context was then tested through a pilot study involving 11 experts from various stakeholder groups in the China AEC industry. At the final stage of the research, a series of semi-structured interviews were conducted to confirm the validity of survey findings. To facilitate and expedite the interview process, all the interviewees were provided with a package of information in advance that included the purpose of the interview, background information, instructions for the exercise and a brief description of the current survey findings. The interviewees were all purposively selected based on their theoretical knowledge of, and practical experience in, BIM adoption in the Chinese AEC industry. To qualify, the interviewees were required to have a minimum of five years of working or research experience in BIM-related disciplines or have previously been involved in the application of BIM for at least two projects in China. Table 3 provides the profiles of the participants, indicating that all interviewees have ample hands-on BIM experience and therefore sufficiently knowledgeable for their opinions to be credible enough for the research.

<Insert Table 3>

3.3 Questionnaire Survey

A draft questionnaire was designed from the results of the literature review and piloted with the 11 interviewees profiled in Table 3 to ensure the questions were intelligible, easy to answer, unambiguous and short enough to be completed within time required. As a result, 12 barriers hindering BIM adoption in the AEC industry were identified (Table 4). A 5-point Likert scale is used to solicit comments from the owner, designer and contractor stakeholder groups regarding the relative importance of each barrier. To improve the reliability of survey findings, all respondents from the three groups were selected on a purposive basis, with the requirement to have a minimum of two years of working or research experience in BIM-related disciplines or have previously been involved in BIM application in at least one project in China.

<Insert Table 4>

A total of 555 questionnaires were dispatched and 136 were returned by post, email or fax (Table 5), representing a response rate of 24.5%. This response rate is common for a survey of this kind and is regarded as acceptable based on the findings of Akintoye (2000).

<Insert Table 5>

4. Data analysis and results

Various analytical techniques were adopted, including the mean score ranking technique, independent sample *t*-tests and ANOVA. As a result, the relative importance of the different BIM adoption obstacles as perceived by each stakeholder group was ranked and any significant perceptual differences identified. The comments raised by the interviewees during the validation interviews were also recorded.

4.1 Ranked barriers of BIM adoption

Chan *et al.* (2009) apply the mean score ranking technique to delineate the importance of different drivers for the adoption of public private partnerships. Using the same technique, the data collected from the questionnaire was analyzed according to the statistic:

$$Mean\ Score = \frac{\sum (f \times s)}{N},\ (1 \leq Mean\ Score \leq 5) \quad (1)$$

where *s* represents the score of each barrier ranging from 1 (least important) to 5 (most important); *f* stands for the frequency of response to each rating (1-5) for each barrier; and *N* denotes the total number of responses concerning a specific barrier.

Based on the responses obtained from the three stakeholder groups, the mean of each BIM application obstacle were calculated and ranked as shown in Table 4 with the scale intervals being: (i) "not important" (mean score ≤ 1.5); (ii) "fairly important" (1.51 ≤ mean score ≤ 2.5); (iii) "important" (2.51 ≤ mean score ≤ 3.5); (iv) "very important" (3.51 ≤ mean score ≤ 4.5); and (v) "extremely important" (mean score ≥ 4.51).

4.1.1. Concerns of owners

The owner representatives give comparatively higher mean scores to majority of the factors (Table 4), with F1 - lack of understanding (4.74); F7 – not sure if the benefits outweigh the costs when implementing BIM (4.72); and F11 - insufficient government lead/direction (4.62) being their top concerns. These results are confirmed by the validation interviews, with five of the six owner interviewees admitting that, although having heard of BIM, their understanding of the concept is still very superficial. The academic contingent further pointed out that a considerable number of Chinese owners simply consider BIM as 3D visualization and that its benefits only arise in clash detection. As a result, they invest prudently in BIM. As commented by two owner interviewees, "We still doubt whether the benefits can outweigh the costs when implementing BIM. Instead, we would rather trust the existing mature technology".

4.1.2. Concerns of designers

Two factors, including F7 – not sure if the benefits outweigh the costs when implementing BIM; and F2 – lack of owner demand) are rated by designers as "extremely important". All the five designer representatives agree that the initial investment in hardware and software for BIM adoption could place heavy financial burdens on the design companies/institutes. The three academic representatives also believe that human capital is insufficient in the current competitive environment and it is costly to train qualified staff. On the other hand, two designers find that the competitive edge of the design companies/institutes with BIM skills (especially those medium and small-sized) is probably not decisive in winning projects when contending with large design enterprises. Instead, owners without BIM requirements are lured away.

4.1.3. Concerns of contractors

As revealed from the questionnaire results, the contractors identify F12 - resistance to change of culture/thinking mode (4.86); F7 – not sure if the benefits outweigh the costs when implementing BIM (4.71); and F3 – lack of experienced BIM professionals (4.51) as extremely important barriers, with two contractor interviewees complaining that "involving BIM in the construction process has disrupted our traditional workflow". The academics explained that it takes time to change from an extensive to intensive management mode and this process, to some extent, conflicts with the benefits of traditional contractors in China. Their comments that "the increased transparency through BIM application may reduce the chances of contractors obtaining extra income from quantity overruns" further illustrate the point.

4.2 Disparity of perceptions between paired stakeholder groups

Independent sample *t*-tests were used to identify any significant differences in the mean scores of the paired groups in relation to their perspectives, with $p < 0.05$ (two-tailed) as the cut-off value (Table 6). Levene's test was also conducted to determine if the variances between the pairs of groups could be assumed to be homogeneous, again with $p < 0.05$ as the cut-off value.

<Insert Table 6>

4.2.1 Owner vs. designer

According to Table 6, five factors vary considerably between the owner and designer groups. These comprise F2 – a lack of owner/contractor demand (*mean difference*=-1.14947); F11 – insufficient government lead/direction (*mean difference*=0.59202); F8 – increased workload and decreased efficiency (*mean difference*=-0.42553); F1 – lack of understanding (*mean difference*=0.41968); and F3 - lack of experienced BIM professionals (*mean difference*=0.36915). Most of the designer group interviewees find that, in addition to the extra cost of hardware/software, adopting BIM may also lead to an increased workload when compared with the traditional design process due to the incorporation of the whole-life cycle concept. As a design director complained, "we have to think from a whole-life cycle perspective rather than merely focusing on the design itself. The decreased efficiency may cause delay in the design period". As a result, design companies/institutes lack the impetus to actively embrace BIM unless there is a strong driver from the owner. Three research institutions/universities interviewees further added that it is reasonable for the owner to play the leading role in promoting BIM implementation since they stand to gain the most from the process. The owner representatives, on the other hand, admitted that most of them are relatively conservative in BIM implementation and urged for stronger support from the government in terms of policy, mandates and incentives.

4.2.2 Owner vs. contractor

Comparing the results of the owner and contractor groups, significant differences in the scores occur in six concern factors (Table 6), with F12 – resistance to change of culture/thinking being the greatest (*mean difference*=-0.68693). It is surprising to note that the vast majority of owners (5 out of 6 involved in the validation interviewees) had an open mind and were willing to make a difference in terms of management mode. After all, the ambiguous attitude towards the thinking/doing nexus is long and deep-rooted in the populace's mind. Still, two owner representatives reminded that the "return of investment (ROI) in BIM remains in question in China since convincing successful cases are normally only from overseas". The government side responded that increasing numbers of pilot BIM projects will be launched in various cities in China in future to guide BIM application in the AEC industry. Greater resistance was expected from the contractor group since the BIM concepts, such as precision, transparency, etc., are contrary to their traditional working mode, and especially the way they can earn extra profits.

4.2.3 Designer vs. contractor

As Table 6 reveals, the designers disagree with the contractors on four concern factors, the most important being F3 – lack of experienced BIM professionals (*mean difference*=-0.56020). Four contractors stated that, although BIM requires design professionals to change their mindset from the conventional 2D to 3D, representation the accessibility of relevant software has made this process much easier. On the other hand, they emphasized that in addition to technical abilities, qualified BIM staff in construction companies should be equipped with detailed knowledge of construction management and be strongly capable coordinators. However, as a chief engineer of a construction company pointed out, *"such adequately trained/experienced professionals are rather scarce"*. The academics admitted that *"very few universities in China have incorporated BIM into the current curriculum system of either undergraduate and postgraduate studies as compared with overseas teaching/learning"*. They are still keen for talent to be cultivated, however, since market demand is ever growing.

4.3 Disparity of perceptions among the three stakeholder groups

One-way ANOVA was used to comprehensively compare the three stakeholder groups. The results are summarized in Table 7. The mean ratings of the concern factors F2 – lack of owner demand (*F* value=24.009), F12 – resistance to change of culture/thinking mode (*F* value=15.920); and F1 – lack of understanding (*F* value=13.890) emerge as the top three conflicts of the three groups. While the designers attribute the current relatively low level of BIM adoption to insufficient owner drivers, the owners again emphasize the important role of government in overcoming the barrier. As a deputy general manager of a real estate corporation stated, a large number of owners in China are conservative (or shortsighted to some extent) and they are currently not willing to risk money in promoting a novel technique such as BIM. Government's policies, mandates and incentives could be a solution.

The academics further added that support from the government could help the owner take the first step so that they can progressively realize the benefits obtained from BIM adoption. As explained by a deputy director of a provincial research institution, "After all, the largest contribution will go to their side as compared with designers or contractors". The contractor representatives, however, find the largest barrier to BIM application not to be the insufficient drive of the owners or government, but that adopting BIM may completely change the unique way in which Chinese contractors normally operate, and hence the resistance is expected to remain. On the other hand, the owners and designers are more willing to change even with the temporary increased workload and decreased efficiency. As commented by the owner and designer representatives "… we need to confirm the benefits outweigh the costs when implementing BIM in the first place". The level of understanding of BIM varies between the three stakeholder groups and the fact that owners have the least understanding is expected. A university professor explained that this phenomenon corresponds with the traditional Chinese management philosophy, which concentrates more on people than technique – commenting that "Improving top management's recognition of BIM will facilitate its promotion. It works for all the three parties considered".

<Insert Table 7>

5. Conclusions

This paper has ranked the relative importance of BIM adoption obstacles in the Chinese AEC industry as perceived by the owner, designer and contractor groups. The owners' understanding of BIM is rather limited and normally is very much related to 3D visualization and clash detection. The designers, on the other hand, attribute the current low level of BIM use to the questionable amount of return of investment in the technology and process. From the perspective of the contractors, having to change their mode of operation appears to be the biggest obstacle involved.

Conflicting perceptions of BIM implementation barriers were also observed between paired stakeholder groups and generally. These conflicts arise from three aspects: (i) drive for adoption; (ii) the traditional culture; and (iii) talent cultivation. A consensus was easily reached among the validation interviewees that owners, as the biggest beneficiary, should bear the greatest responsibility for promoting BIM, with a key issue being the roles the government and the market should play in assisting the process. Under current circumstances, government mandates and incentives seem more useful given the political-social-economic-cultural environment in China. Traditional Chinese culture encourages thinking/doing in a more ambiguous manner that violates BIM's emphasis on precision. While owners and designers may embrace the change involved and that the use of BIM can lead to a reasonable return on investment, the resistance of contractors seems inevitable and rather difficult to address. After all, they stand to suffer the most since the way they previously earned extra profits would no longer be possible. The conventional management philosophy in China pays more attention to people, with technique being relatively less important. This has led to an insufficient understanding of BIM among senior management and especially owners. Educating decision-makers is therefore likely to be a positive and effective method to facilitate increased BIM use. Talent cultivation, on the other hand, involves far more than just deepening the knowledge of senior management. It requires qualified BIM professionals to be capable of operating the software and managing construction as well as coordinating team members. In this regard, research institutions/universities in China still have a long road to travel. For the next step, more effort needs to be directed at identifying and implementing other possible means of removing the barriers to BIM adoption, through which a framework can be established to fully exploit this revolutionary technology in the Chinese AEC industry in future.

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Table 1: The BIM Definitions

Country/region	BIM definition	Reference
USA	'*A BIM is a digital representation of the physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its lifecycle from inception onward.*'	NIBS, 2007
	'*Building Information Modeling is the development and use of a multi-faceted computer software data model to not only document a building design, but to simulate the construction and operation of a new capital facility or a recapitalized (modernized) facility. The resulting Building Information Model is a data-rich, object-based, intelligent and parametric digital representation of the facility, from which views appropriate to various users' needs can be extracted and analyzed to generate feedback and improvement of the facility design.*'	GSA, 2007
	'*A collection of defined model uses, workflows, and modeling methods used to achieve specific, repeatable and reliable information results from the model. Modeling methods affect the quality of the information generated from the model. When and why a model is used and shared, impacts the effective and efficient use of BIM for desired project outcomes and decision support.*'	DVA, 2010
	'*An electronic representation of a facility for the purpose of design, analysis, construction and operation. A BIM consists of geometric, 3D representations of the building elements plus additional information that needs to be captured and transferred in the AEC delivery process and in the operations process of a facility.*'	AGC, 2010
	'*Building Information Modeling (BIM) refers to a digital collection of software applications designed to facilitate coordination and project collaboration. BIM can also be considered as a process for developing design and construction documentation by virtually constructing the building on the computer before actually building it.*'	DDC, 2012
	'*Building Information Modelling is digital representation of physical and functional characteristics of a facility, creating a shared knowledge resource for information about it and forming a reliable basis for decisions during its life cycle, from earliest conception to demolition.*'	NBIMS, 2014
	'*BIM is one of the most promising developments that allows the creation of one or more accurate virtual digitally-constructed models of a building to support design, construction, fabrication, and procurement activities through which the building is realized.*'	Eastman *et al.*, 2011

UK	'*The effective collection and reuse of project data in order to reduce errors and increase focus on design and value.*'	AEC, 2009
	'*A shared digital representation of the physical and functional characteristics of any built object (including buildings, bridges, roads, etc.) that forms a reliable basis for decisions.*'	BSI, 2010
	'*BIM is essentially value creating collaboration through the entire life-cycle of an asset, underpinned by the creation, collation and exchange of shared 3D models and intelligent, structured data attached to them.*'	BIM Task Group, 2013
Denmark	'*A method that is based on a building model containing any information about the construction. In addition to the contents of the 3D object-based models, this is information such as specifications, building element specifications, economy and programmes.*'	Bips, 2007
	'*A modelling concept in which all parties create and use consistent digital information throughout the life of a construction project. This involves not only CAD and object data, but also any information relating to a project, such as detailed solutions, specifications and project documentation such as minutes of meetings etc.*'	
The Netherlands	'*The integral 3D information source model of the building as constructed with BIM objects in a BIM modelling application. The BIM may consist of multiple individual models, for instance for separation per discipline or aspect. The BIM contains all building information necessary for the production of the required BIM extracts.*'	MIKR, 2012
Hong Kong	'*The process of generating and managing building data during its life cycle. Typically, it uses three-dimensional, real-time, dynamic building modelling software to increase productivity in building design and construction. The process produces the Building Information Model (also abbreviated BIM), which encompasses building geometry, spatial relationships, geographic information, and quantities and properties of building components.*'	Hong Kong Institute of BIM, 2011

Table 2: Barriers to BIM application in the AEC industry in different countries and regions.

Countries and regions	Barriers to BIM application in the AEC industry
UK (Khosrowshahi and Arayici, 2012)	1) Firms are not familiar enough with BIM use 2) Reluctance to initiate new workflows or train staff 3) Benefits of implementation do not outweigh the costs of implementation 4) Benefits are not tangible enough to warrant its use 5) Does not offer enough financial gain to warrant its use 6) Lacks the capital to invest in the hardware and software involved 7) Too risky from a liability standpoint to warrant its use 8) Resistance to a change in culture 9) No demand for its use
Australia (Newton and Chileshe, 2012)	1) Lack of understanding 2) Education and training costs 3) Start-up costs 4) Changing the ways firms do business 5) Finding trained staff 6) Administrative costs 7) Collaboration between disciplines 8) Sharing information 9) Data ownership 10) Interoperability between models
New Zealand (Stanley and Thurnell, 2014)	1) Lack of software compatibility restricts its use 2) The setup cost inhibits its use i.e. software, training and hardware costs 3) Increased risk exposure discourages companies e.g. legal issues such as ownership of BIM models 4) Cultural resistance in companies hinders its effectiveness 5) Incompatibility with industry-recognized element formats for cost planning prevents companies from adopting the software 6) Incompatibility with current Standard Methods of Measurement 7) Lack of integration in the model decreases the reliability and effectiveness of 5D (3D plus time and cost) (e.g. Arch./Eng./MEP designers are not all working off the same model) 8) Lack of protocols for coding objects within BIM models by designers hinder the development of cost modeling using BIM (e.g. lack of complete specification information in BIM models inhibits accurate quantity generation for estimating) 9) Some companies feel their current software meets their needs, so see no need to change 10) The fragmented nature of the construction industry limits its potential 11) Lack of an electronic standard for coding BIM software to Standard Methods of Measurement limits the potential of BIM for cost modeling
Malaysia (Memon *et al.*, 2014)	1) Lack of competent staff to operate the software 2) Unawareness of the technology 3) Non availability of a parametric library 4) Expensive software 5) Not ready to distort the normal operational structure 6) Takes longer time to develop the model 7) Difficult to learn 8) No enforcement from owner
Iran (Kiani *et al.*, 2015)	1) Lack of legal backing from authority 2) Lack of skilled BIM software operators 3) High price of software 4) Benefits of using BIM-based scheduling and planning are not tangible 5) Not required by owners

	6)	Takes longer time to develop a schedule
	7)	Request by other team members
	8)	Costly hardware
	9)	Request by owner in limited phases of projects
	10)	Learning difficulty of BIM tools
	11)	Request by owner in phase of construction
	12)	Availability of drawings and specifications in the design phase
	13)	No need to change conventional methods
	14)	CPMs resistance to change
	15)	Availability of teaching aids of BIM-based scheduling
	16)	Availability of related courses in universities
Hong Kong (Chan, 2014)	1)	Lack of qualified in-house staff to carry out the BIM related works
	2)	Lack of training/education
	3)	Lack of standards
	4)	Lack of owner demand
	5)	Lack of government lead/direction
	6)	Lack of incentive to have subcontractors and suppliers (lower part of the supply chain) adopt BIM
	7)	High cost
	8)	Uncertainties over interoperability of BIM software with other software
	9)	Lack of IT infrastructure
	10)	Uncertainties over ownership of data and responsibilities
	11)	Lack of new and/or amended forms of construction contracts
	12)	Current professional indemnity and insurance terms
Nigeria (Abubakar *et al.*, 2014)	1)	Social and habitual resistance to change
	2)	Legal and contractual constraints
	3)	High cost of training
	4)	Lack of enabling environment (government policies and legislations)
	5)	Lack of trained professionals to handle the tools
	6)	Owners not requesting the use of BIM on projects
	7)	No proof of financial benefits
	8)	High cost of integrated software/models for all professionals
	9)	Lack of standards to guide implementation
	10)	Poor internet connectivity
	11)	Frequent power failure
	12)	Lack of awareness of the technology among industry stakeholders

Table 3: The Profiles of the Interviewees

Group	No.	Position	Organization	Research Stage Involved	
				Pilot Study	*Validation*
Owner	1	Project Manager	Real Estate Corporation	√	
	2	Senior Consultant	Investment Corporation	√	
	3	Quantity Surveyor	Real Estate Corporation	√	
	V1	Engineering Manager	Real Estate Corporation		√
	V2	Deputy General Manager	Real Estate Corporation		√
	V3	Technical Director	Railway Company		√
	V4	Chief Engineer	Real Estate Corporation		√
	V5	Deputy General Manager	Subway Construction Office		√
	V6	Civil Engineer	Real Estate Corporation		√
Designer	4	Senior Architect	Design Consultants	√	
	5	Chief Engineer	Design Institute	√	
	V7	Vice President	Design Institute		√
	V8	Technical Director	Design Company		√
	V9	Associate Architect	Design Institute		√
	V10	Chief Planner	Design Company		√
	V11	Design Director	Design Institute		√
Contractor	6	Deputy General Manager	Construction Company	√	
	7	Engineering Manager	Construction Company	√	
	V12	Chief Engineer	Construction Company		√
	V13	Technical Manager	Construction Company		√
	V14	Deputy Engineering Manager	Construction Company		√
	V15	Project Manager	Construction Company		√
	V16	Deputy Technical Manager	Construction Company		√
Government Department	8	Policy Advisor	Provincial Department	√	
	9	Deputy Director	Municipal Department	√	
	V17	Deputy Director	Provincial Department		√
	V18	Director	Municipal Department		√
	V19	Deputy Director	Provincial Department		√
	V20	Deputy Secretary-general	Municipal Department		√
	V21	Deputy Director	Municipal Department		√
Research Institution/ University	10	Deputy Director	National Research Institution	√	
	11	Professor	University	√	
	V22	Senior Research Fellow	University		√
	V23	Associate Professor	University		√
	V24	Deputy Director	Provincial Research Institution		√
	V25	Associate Research Fellow	Provincial Research Institution		√
	V26	Professor	University		√

Table 4: Perceptions of Various Stakeholder Groups regarding the Barriers of BIM Adoption in the AEC Industry in China

No.	Barriers of BIM Adoption in the Chinese AEC Industry	Stakeholder Group							
		Owner		Designer		Contractor		Overall	
		Mean Score	Ranking	Mean Score	Ranking	Mean Score	Ranking	Mean Score	Ranking
F1	Lack of understanding	4.74	1	4.33	4	4.08	9	4.38	4
F2	Lack of owner demand	3.43	12	4.58	2	4.06	11	3.99	9
F3	Lack of experienced BIM professionals	4.32	6	3.95	10	4.51	3	4.28	7
F4	High costs of education and training	4.34	5	4.27	6	4.39	5	4.34	5
F5	High costs of hardware and software	4.43	4	4.47	3	4.41	4	4.43	3
F6	Lack of applicability and practicability regarding the BIM software	3.87	9	3.93	11	4.08	9	3.96	10
F7	Not sure if the benefits outweigh the costs when implementing BIM	4.72	2	4.72	1	4.71	2	4.72	1
F8	Increased workload and decreased efficiency	3.57	10	4.00	9	4.02	12	3.86	11
F9	Lack of standards, laws and regulations	4.26	7	4.18	7	4.22	7	4.22	8
F10	Insufficient information sharing	3.55	11	3.80	12	4.20	8	3.86	11
F11	Insufficient government lead/direction	4.62	3	4.02	8	4.31	6	4.33	6
F12	Resistance to change of culture/thinking mode	4.17	8	4.30	5	4.86	1	4.46	2

Table 5: Response Rate

Stakeholder group	*No. of questionnaires*		*Percentage return*
	Sent	*Return*	
Owner	186	47	25.3%
Designer	178	40	22.5%
Contractor	191	49	25.7%
Total	**555**	**136**	**24.5%**

Table 6: Results of Independent Sample *T*-Tests between Paired Stakeholder Groups for Their Perceptions regarding BIM Adoption Barriers

Paired Stakeholder Groups	***Stakeholder perceptions with significant differences***	***Equal variances assumed***	***Levene's test for equality of variances***		***T-test for equality of means***				
			F	*Sig.*	*t*	*df*	*Sig. (2-tailed)*	*Mean diff.*	*Std. error diff.*
Owner vs. designer	F1	N	8.925	.004	3.598	69.281	.001	.41968	.11664
	F2	N	19.750	.000	-6.691	72.894	.000	-1.14947	.17180
	F3	Y	.000	.990	2.633	85	.010	.36915	.14022
	F8	N	16.192	.000	-3.652	84.939	.000	-.42553	.11651
	F11	Y	.040	.841	4.626	85	.000	.59202	.12797
Owner vs. contractor	F1	N	8.913	.004	5.258	77.649	.000	.66305	.12609
	F2	N	18.197	.000	-3.621	78.348	.001	-.63569	.17554
	F8	N	5.699	.019	-3.718	93.971	.000	-.44594	.11993
	F10	Y	3.395	.069	-4.913	94	.000	-.65089	.13248
	F11	Y	3.748	.056	2.630	94	.010	.31090	.11822
	F12	N	38.605	.000	-5.182	67.031	.000	-.68693	.13256
Designer vs. contractor	F2	Y	.408	.525	3.939	87	.000	.51378	.13042
	F3	Y	.001	.970	-4.196	87	.000	-.56020	.13350
	F10	Y	.172	.679	-3.017	87	.003	-.40408	.13391
	F12	N	17.376	.000	-4.957	65.780	.000	-.55714	.11239

Note: 2-tailed sig.<0.05

Table 7: Disparity of Perceptions among the Three Stakeholder Groups

Barriers of BIM adoption in the Chinese AEC industry		***Sum of squares***	***df***	***Mean square***	***F***	***Sig.***
F1	Between groups	10.733	2	5.367	13.890	.000
	Within groups	51.385	133	.386		
	Total	62.118	135			
F2	Between groups	28.912	2	14.456	24.009	.000
	Within groups	80.081	133	.602		
	Total	108.993	135			
F3	Between groups	7.025	2	3.512	9.276	.000
	Within groups	50.358	133	.379		
	Total	57.382	135			
F8	Between groups	5.877	2	2.938	9.202	.000
	Within groups	42.469	133	.319		
	Total	48.346	135			
F10	Between groups	10.369	2	5.185	12.319	.000
	Within groups	55.976	133	.421		
	Total	66.346	135			
F11	Between groups	7.621	2	3.810	10.037	.000
	Within groups	50.490	133	.380		
	Total	58.110	135			
F12	Between groups	12.697	2	6.348	15.920	.000
	Within groups	53.038	133	.399		
	Total	65.735	135			

Note: sig.<0.05