Ahuja, R, Sawhney, A, Jain, M, Arif, M and Rakshit, S

Factors influencing BIM adoption in emerging markets—the case of India

Factors influencing BIM adoption in emerging markets—the case of India

Ritu Ahuja [a], Anil Sawhney [b*], Megha Jain [c], Mohammed Arif [d] and Samya Rakshit [a]

[a] *RICS School of Built Environment, Amity University, Noida, India;*

[b] *Department of Built Environment, Faculty of Engineering and Technology, Liverpool John Moores University, Liverpool, UK;*

[c] *School of Business, Middlesex University, Dubai, UAE;*

[d] *Architecture and Built Environment, University of Wolverhampton, Wolverhampton, UK*

[a*] Professor, Department of Built Environment, Liverpool John Moores University, Byrom Street, Liverpool, L3 3AF UK; +44 151 231 2842; a.sawhney@ljmu.ac.uk

Factors influencing BIM adoption in emerging markets—the case of India

This paper studies the adoption of Building Information Modelling (BIM) in emerging markets. The factors responsible for the adoption of BIM are studied in the context of Indian architectural firms. The mechanisms of diffusion of BIM are analysed through a questionnaire survey based on the Technology–Organization–Environment (TOE) framework which broadly categorises the influencing factors along these three dimensions. Data were collected through a web-based questionnaire survey. The 184 valid responses were analysed using descriptive statistics. The study found that full potential of BIM has been explored but not realised by many in the Indian construction sector. Findings of the study are analysed and compared with other emerging and developed markets. Based on the survey results, recommendations for increasing the BIM adoption are provided. Further studies and learnings from mature markets can help Indian construction sector develop effective BIM implementation strategies.

Keywords: Building Information Modelling (BIM); Technology –Organization – Environment (TOE) framework; Architectural firms; BIM Adoption; Indian construction sector

Importance of BIM for the construction sector and the Indian context

One of the most remarkable recent innovations for systemic improvement in the construction sector is Building Information Modelling (BIM). Adoption of BIM leads to a wide range of benefits that include improved productivity, enhanced quality, and increased opportunities for new businesses (McGraw Hill Construction 2014). Various researchers (Arayici et al. 2011; Navendren et al. 2014; Ramilo and Embi 2014) show that BIM adoption leads to efficiency gains in small and medium architectural firms. However, several studies (Sawhney, 2014a) highlight the stark contrast of BIM adoption among different countries: 71% in the USA, 61% in Australia (McGraw Hill Construction 2014), 62% in the UK (NBS 2017), 36% in Europe, and 25% in the Middle-East (Sawhney et al. 2017). On the other hand, BIM adoption in India is only at 10-18 % (Sawhney 2014b).

Developing countries face the recurrent problems of project delays and cost overruns (Sahil 2016). Since one issue that BIM addresses is design errors, a major cause for delays leading to significant negative time and cost impact (Won et al. 2013), it's use could improve the situation in developing countries.

In this study, we investigate the factors influencing BIM adoption in one of the fastest growing developing countries, India (OECD 2017). The construction sector in India is the second largest employer and contributor to the GDP of India (Department of Policy and Promotion; Planning Commission, 2011) and is likely to become the third largest construction market globally by 2025 (Oxford Economics 2016). However, at present, this industry faces various challenges such as low productivity, limited mechanisation, and lack of professionally qualified architects, engineers and construction project managers (Doloi et al. 2012; Sawhney et al. 2014). The Indian construction industry, like many other developing countries, has a low rate of technology adoption. Increased use of Information and Communication Technology (ICT) and ICT-based solutions is extremely important (Planning Commission 2013) and it is therefore important to study and facilitate the adoption of BIM in the Indian construction sector.

BIM adoption journey

BIM adoption at an organisational level goes through several stages (Succar 2010). The first stage is object-based modelling spread across various disciplines; the second, model-based collaboration and the third is a network-based collaboration (Succar 2010). This stage or level-based adoption-model has now been used in the UK by defining BIM levels 0, 1, 2 and 3 (UKBIMA 2016), the USA (Chew and Riley 2013), Singapore (Building and Construction Authority 2012) and Australia (NATSPEC 2011) to understand and facilitate greater and deeper BIM adoption. In contrast, developing countries do not have such industry-wide guidance available to support the BIM adoption journey. For example, the maturity level of BIM adoption in India is thought to be at the lower end of the spectrum, since collaboration and coordination aspects of BIM are absent (Sawhney 2014b). The level of adoption of BIM is also reported to be low in China (Gong 2012; NBS 2016) and Brazil (Kassem 2016).

Design professionals have been the earliest BIM adopters (McGraw Hill Construction 2014), and in most instances, architectural firms are ahead in implementing BIM. Elmualim and Gilder (2014) found that of other organisations the design team usually encourages the use of BIM on projects.

There is limited information available regarding BIM adoption patterns and maturity levels in emerging markets. Therefore the purpose of this study is to identify and compare the presence of possible BIM adoption drivers and inhibitors in adopting and non-adopting firms, within the Indian context. This study also compares adoption patterns and other pertinent findings between emerging markets and mature markets, ultimately framing recommendations for greater levels of adoption in the case of emerging markets.

Literature review

Several studies have been conducted in various part of the world to understand BIM adoption (McGraw Hill Construction 2014; NBS 2016; NBS 2017), factors influencing BIM adoption and use of BIM itself (Gu and London, 2010; Linderoth, 2010; Sawhney, 2014b; Xu, Feng, and Li, 2014). However, this study is the first to identify different factors, which either encourage or prevent BIM adoption in the Indian context among architectural firms.

There are several theories of technology diffusion and adoption, particularly concerning information systems (Sharma and Mishra 2014). Many papers have highlighted that technology adoption is not only a function of the efficiency of the technology but is also dependent on characteristics of the user (Venkatesh et al. 2014), social attitude (Fishbein and Ajzen 1975), trust (Gefen and Straub 1997) and other causal factors (Thompson et al. 1991). The theories of technology adoption can be broadly classified according to the Table 1 as follows:

Table 1: Theories of Technology Adoption

Type of Theory	**Name of Theory**	**Explanation**
Technology adoption at individual level (Davis et al. 1992; Compeau and Higgins 1995)	Theory of Reasoned Action (TRA) (Fishbein and Ajzen 1975)	Three general constructs: Behavioural Intention (BI), Attitude (A) and Subjective Norm (SN). The behavioural intention of a person is influenced by his or her attitude and subjective norms.
	Theory of Planned Behaviour (TPB) (Ajzen 1991)	The concept of Perceived Behavioural Control added to the pre-existing TRA (Sharma and Mishra 2014). Perceived Behavioural Control signifies the "people's perception of the ease or difficulty of performing the behaviour of interest".
	Technology Acceptance Model (TAM) (Davis 1989)	Based on two parameters: “perceived usefulness” and “perceived ease of use” (Sharma and Mishra 2014). These parameters are arrived at from the “self-efficacy theory” (Bandura and Cervone 1986) and the study by Roger and Shoemakers (1971).
	Unified Theory of Acceptance and Use of Technology (UTAUT) (Chiyangwa and	Four key constructs: performance expectancy, effort expectancy, social influence and facilitating conditions. It was framed to synthesise all the existing theories of technology adoption at an individual level.

	Alexander, 2016; Venkatesh et al., 2014)	
Technology adoption at organisation level (Leonard-Barton and Deschamps 1988)	Diffusion of Innovation Model (DIM) Theory (Rogers 2003)	Considered a seminal work in the diffusion literature (Sharma and Mishra 2014), it investigated the means by which technology diffusion happens, through a community with the passage of time (Kaur Kapoor et al. 2014). Both *efficiencies in obtaining information* and *influence of society* were considered relevant in this type of *social contagion model* (Deligiannaki and Ali 2011). DIM proposed that groups of adopters have a different type of response to a technology considering the time of adoption (Chiyangwa and Alexander, 2016).
	Technology, Organization and Environment (TOE) Framework (Tornatzky et al. 1990)	Described three facets of a firm's context in its decision to adopt technology: technological, organisational and environmental. This framework was consistent with DIM (Oliveira and Martins, M 2011) since it incorporated characteristics of both the individual and the organisation. However, it also included a new factor—the *environmental*, which is why the TOE framework has been said to be better in explaining intra-firm innovation diffusion (Hsu et al. 2006; Oliveira and Martins, M 2011). Research

		areas of information technology and commerce have constantly seen many successful applications of TOE based empirical research (Xu et al. 2004; Zhu and Kraemer 2005; Lin and S.M. Lin 2008; Jain et al. 2011).

Research areas of information technology and commerce have constantly seen many successful applications of TOE based empirical research (Xu et al. 2004; Zhu and Kraemer 2005; Lin and Lin 2008; Jain et al. 2011). The key reason for this success is that the TOE framework uses three facets of a firm's context in its decision to adopt technology: technological, organisational and environmental. This framework was consistent with DIM (Oliveira and Martins 2011) since it incorporated characteristics of both the individual and the organisation. However, it also included a new factor—the environmental, which is why the TOE framework has been said to be better in explaining intra-firm innovation diffusion (Hsu et al. 2006; Oliveira and Martins 2011). Therefore the TOE-based framework was used for this study.

A literature review of ICT adoption was conducted to identify the constructs within TOE framework,. Al-Qirim (2007) found the relationship between complexity, compatibility, top-management support, and innovation adoption to be significant. This is true, while it found that the relationship between Information Systems (IS) expertise, trialability and innovation adoption as insignificant, a belief in congruence with other studies (Mirchandani and Motwani 2001; Huang et al. 2008). Similarly, Premkumar and Roberts (1999), in studying the state of use of various communication technologies, asserted that top-management support, IT expertise, complexity, compatibility and perceived cost have a significant impact on technology adoption. A study conducted on the determinants of e-business diffusion (Lin and

Lin 2008), concluded that IS expertise and trading partner readiness are important factors for successful e-business diffusion. Research in the IT sector by Roberts and Pick (2004), confirmed top management support as a significant factor that promotes technology adoption. Similarly, the study by Balocco, Mogre and Toletti (2009) asserted that clarity on benefits from return on investments could increase the adoption rate of IT applications. In addition to above, the study by Kuan and Chau (2001) affirmed the significant effect of perceived cost, IS expertise and regulatory support while investigating the adoption of electronic data interchange by U.S. enterprises. Similar studies by Zhu and Kraemer (2005) regarding diffusion and consequences of e-business at the firm level, also asserted regulatory support and trade partner readiness as significant factors. Another study by Dasgupta, Agarwal, Ioannidis and Gopalkrishnan (1999) confirmed that regulatory support and IS expertise are significant factors which help the organisations to make decisions regarding information technology adoption. These factors, summarised in Table 2, formed the basis of the study conducted by the authors.

Table 2: TOE Construct from literature

Constructs	**Sources**
Complexity	(Premkumar and Roberts 1999; Al-qirim 2007)
Compatibility	(Premkumar and Roberts 1999; Al-qirim 2007)
Trialability	(Mirchandani and Motwani 2001; Huang et al. 2008)
Top Management Support	(Premkumar and Roberts 1999; K.G. Roberts and Pick 2004b; Al-qirim 2007)
Perceived costs	(Premkumar and Roberts 1999; Kuan and Chau 2001; Balocco et al. 2009)

Expertise	(Premkumar and Roberts 1999; Mirchandani and Motwani 2001; Huang et al. 2008; Lin and S.-M. Lin 2008)
Trade Partner Readiness	(Zhu and Kraemer 2005; Lin and S.M. Lin 2008)
Client Requirement	(Soon and Gutiérrez 2003; Doolin and Al Haj Ali 2008)
Regulatory Support	(Dasgupta et al. 1999; Zhu and Kraemer 2005)

Research methodology

The TOE framework was used to develop a survey instrument for collecting primary data from industry experts. After combining these studies with the literature review as discussed in this section, TOE framework was adopted for the current research, and a model was proposed for BIM adoption with different identified and relevant TOE factors with constructs defined as listed in Table 3.

Table 3: Definition of TOE constructs for BIM adoption

Group	**Constructs**	**Definition and Reason for Consideration**
Technological Factors	Complexity	When innovation is relatively complex to use and understand, it is termed as complex (Kumar and Swaminathan 2003). Various sources have cited that with increasing difficulty of use, the adoption rate of a technology decreases (Howard and Björk 2008;

		Kunz and Fischer 2012; Newton and Chileshe 2012).
	Compatibility	The degree to which an innovation is perceived as being consistent with existing beliefs, values and needs of the adopter (Rogers 2003). New technology can herald substantial changes in work practice which can be difficult for organisations to incorporate (Premkumar and Roberts 1999)
	Trialability	The extent of experimentation available with any innovation on a limited basis is defined as Trialability (Kumar and Swaminathan 2003) Trialability has been described as the property by which the various benefits accrued from adoption of technology can be examined without putting the firm's core at risk (Panuwatwanich and Peansupap 2013)
Organizational Factors	Top Management Support	The supportive climate and resources received from top management for adoption of new technologies (Premkumar and Roberts 1999) It has been found that greater support from the top management leads to BIM adoption benefits (Gu and London 2010; Xu et al. 2014; Cao et al. 2015)
	Perceived costs	The perceived cost is categorised into one-time setup costs and general system-related costs. A lower perceived cost facilitates the adoption of innovation. (Bouchbout and Alimazighi 2008)
	Expertise	The availability of skilled and technological experts has been found to be positively related

		to adoption (Crook and Kumar 1998). Studies suggest that firms with technologically experienced employees have a greater propensity to adopt new technology (Lin and Lee 2005; Eastman et al. 2011)
Environmental Factors	Trade Partner Readiness	Good partner relationships is found be a significant determinants of inter-organisational systems adoption and implementation (Grover 1993)
	Client Requirement	Owner's innovativeness: willingness to adopt new ideas/technological innovations plays a significant role in technology adoption (Al-qirim 2007)
	Regulatory Support	Regulatory factors may affect technology diffusion across different countries (Zhu and Kraemer, 2005)

A web-based questionnaire, based on the TOE framework (Table 4), pretested with five architects to check for inconsistency, was sent to experts within the Indian architectural firms.

To omit common method bias, several steps were taken in framing the questionnaire. These included protecting respondent identity, using pre-validated scales, reducing evaluation apprehension, counterbalancing of question order and the use of verbal midpoints for measures (Podsakoff et al. 2003).

The sample of Indian architecture, engineering and construction (AEC) industry professionals who are either architects or are significantly involved in architectural practice was drawn from membership database of Royal Institution of Charted Surveyors, India and a popular construction industry magazine. The two databases used in this study very well represented the Indian construction sector.

The initial and follow-up questionnaire requests resulted in 413 responses out of which 184 valid responses were eventually collected and analysed using descriptive statistics (the reason for a large number of invalid responses was that the criteria that respondents who were either architects or were significantly involved in the architectural practice such as design managers, project managers, and other professionals working in architectural firms were selected). Assuming there are 53,696 architects in India (Council of Architecture 2017), a sample size of 184, with 95% confidence interval, has a margin of error 8% (Vidakovic 2014).

Table 4: Structure of the Questionnaire

No.	**Focus**	**Target Respondents**
1	Participant Profile	All the respondents
2	Participant's Job Profile	
3	Organization's Details	
4	BIM adoption in the organisation	
5	Analysis of technological aspects of BIM	BIM adopters and non – adopters
	5.1 Complexity (Premkumar and Roberts 1999; K G Roberts and Pick 2004; Al-qirim 2007; Huang et al. 2008; Ramdani et al. 2009; Jain et al. 2011) 5.2 Compatibility (Premkumar and Roberts 1999; K G Roberts and Pick 2004; Al-qirim 2007; Huang et al. 2008; Lin and S.M. Lin 2008; Ramdani et al. 2009) 5.3 Trialability (K G Roberts and Pick 2004; Al-qirim 2007; Ramdani et al. 2009; Jain et al. 2011)	

6	Analysis of organisational aspects of BIM	BIM adopters and non – adopters
	6.1 Top Management Support (Premkumar and Roberts 1999; Al-qirim 2007; Huang et al. 2008; Ramdani et al. 2009) 6.2 Perceived Cost (Kuan and Chau 2001; K G Roberts and Pick 2004; Lin and S.M. Lin 2008; Balocco et al. 2009) 6.3 BIM expertise (Dasgupta et al. 1999; Premkumar and Roberts 1999; Al-qirim 2007; Ramdani et al. 2009; Jain et al. 2011)	
7	Analysis of environmental aspects of BIM	BIM adopters and non – adopters
	7.1 Client Requirement (Al-qirim 2007) 7.2 Trade Partner Readiness (Zhu et al. 2003; Lin and S.M. Lin 2008; Jain et al. 2011) 7.3 Regulatory Support (Dasgupta et al. 1999; Zhu and Kraemer 2005)	
8	Impact of BIM on trust and performance	Participants who have already adopted BIM

Findings from the survey

The survey resulted in useful insights on the current status of BIM usage and adoption within architectural firms in India. The survey shows that out of the total 184 complete responses, 42% of the respondents have over 15 years of professional experience in the industry and 16% of the respondents have professional experience between 10-15 years. As most of the respondents had above ten years of experience, this suggests that the respondents had a holistic knowledge of the Indian AEC industry. 50% of the respondents reported that they were using BIM in their organisations and 50% of the respondents reported that their organization is not using BIM (refer Figure 1). Non-adopters were routed to a different section of the survey where they were asked to respond to the BIM adoption questions based on their current understanding and perceptions.

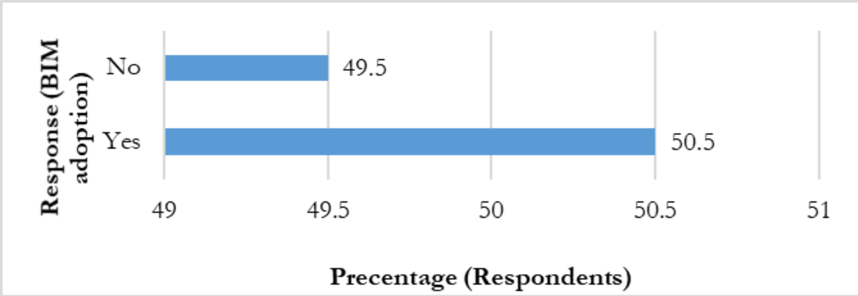

Figure 1: Organizations using BIM on projects

Technological factors

According to literature, lack of awareness of and exposure to BIM constitutes a major hurdle in its more extensive use, in several countries like the UK (Khosrowshahi and Arayici 2012), Ireland (Mcauley et al. 2013) and Malaysia (Zahrizan et al. 2014). In such a situation, exposure to software on a trial basis might provide a stepping-stone to widespread BIM-acceptance. Figure 2 shows that permission to use trial software functionality on pilot projects was available to 56% of the total number of respondents with 46% of the BIM adopters reporting the same. In line with the BIM adopters, 42% of the non-adopters also agreed on the importance of the use of software functionality on trial basis, with 43% asserting that software should be available for a timeframe long enough to explore its potential benefits.

Only 41% of the BIM adopters and 30% of non-adopters believe that BIM related software is not complex to use. 33% of BIM adopters pointed out that BIM related software is complex to use and 39% non-adopters have a similar perception. An equal number of respondents, with 40% adopters stated that it is not only the software but also the BIM implementation process which is complex. When asked 41% of non-adopters perceived that the BIM implementation process is complex prompting them to delay adoption. One of the reasons for this can be the lack of standards and well-laid-out processes, as compared to other countries.

Although some BIM adopters and non-adopters reported the perceived complexity of BIM software, 63% of adopters and 60% of non-adopters stated that BIM process is consistent with their beliefs and values. Along with this, 70% of BIM adopters and 46% of non-adopters mentioned that there has always been a favourable attitude towards BIM adoption in their organisation, while 66% BIM adopters and 48% non-adopters have confirmed that BIM is compatible with their existing practices. This readiness to incorporate BIM within Indian firms has also been observed in the literature (Yan and Damian 2008).

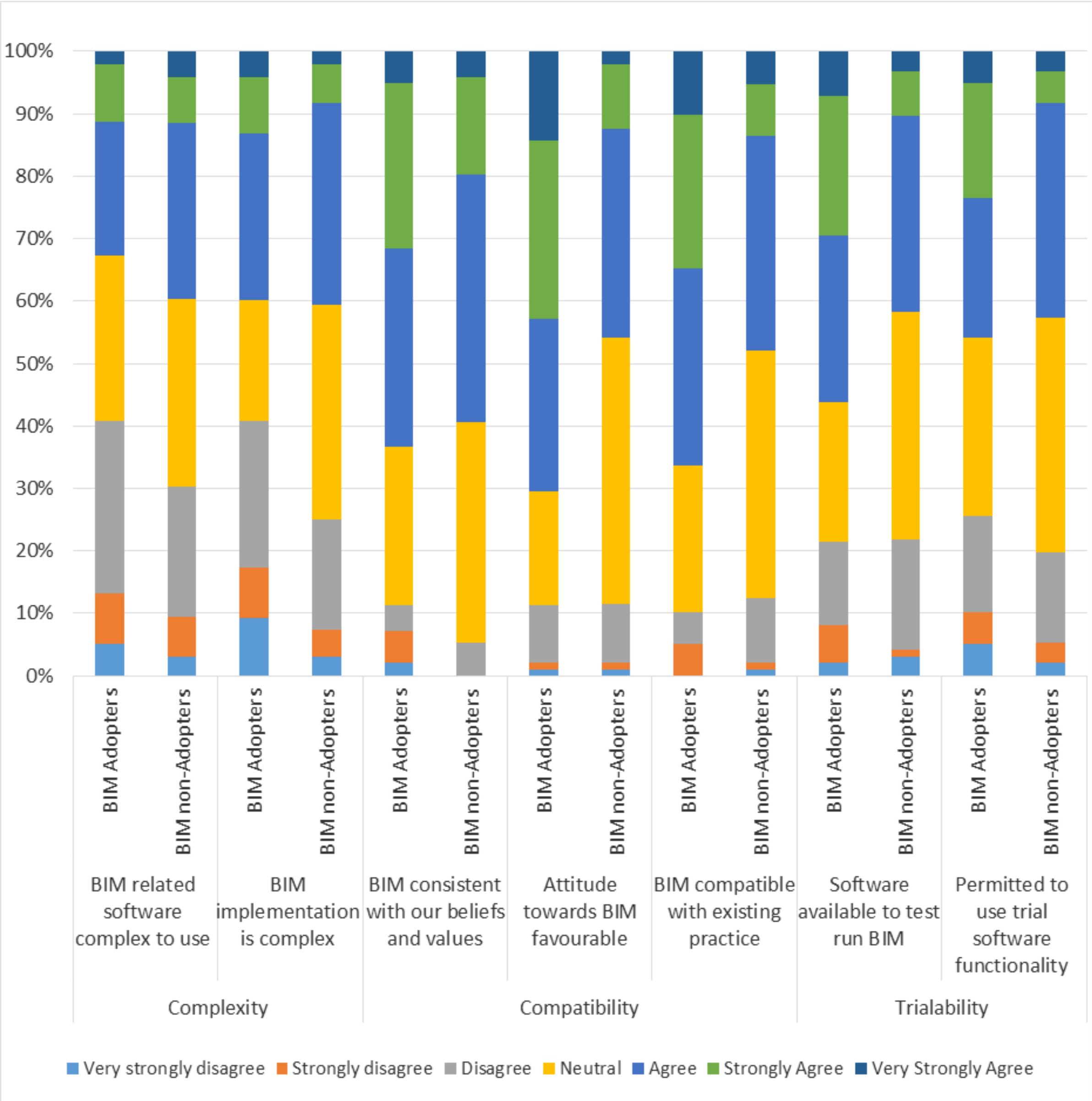

Figure 2: Technological factors affecting BIM adoption decision

Organizational factors

The study reveals that top management support is one of the major drivers for BIM adoption. A total of 75% of BIM adopters and 50% of non-adopters have reported that top management in their firm has always shown an interest in the implementation of BIM. Along with this, 74% of BIM adopters and 42% of non-adopters have also mentioned that top management in their organisation has effectively communicated their support for BIM implementation. The importance of the role of top management has also been highlighted elsewhere in the context of Singapore (Attarzadeh et al. 2015).

The survey results (Figure 3) highlight that one of the challenges faced by BIM adopters, is the perceived cost of BIM—including high set-up, running and training cost. This was reported by 54% of BIM adopters and 54% of non-adopters. Again, 52% of BIM adopters and 55% of non-adopters also reported long lead time for full-scale BIM implementation as another obstacle. Along with this, respondents felt that organisations find it challenging to measure the return on investment on BIM since they do not have clarity on the value proposition especially on Indian projects. That many in the AEC industry have no clear understanding of the accrued benefits for BIM is also noted in the context of the United Kingdom (Khosrowshahi and Arayici 2012), Ireland (Mcauley et al. 2013) and Nigeria (Abubakar et al. 2014). Enterprises are also unwilling to invest in BIM due to this reason in China (Geng 2011) and Malaysia (Zahrizan et al. 2014).

BIM expertise is reported to be one of the major influencing factors for BIM adoption. It is seen that awareness level regarding BIM is high amongst the adopters with 62% confirming that the employees in their organisations are aware of BIM functions. However, the awareness level amongst non-adopters is relatively low—with only 30% having employees with an awareness of BIM functions. It is also seen that although 55% of BIM adopters reported that their firm has highly specialised or knowledgeable personnel for BIM processes and implementation. 58% of non-adopters had no such specialisation in their organisations. Similarly, 46% of BIM adopters confirmed that their employees are well trained in BIM. 66% of non-adopters did not have employees capable of handling BIM. It is concluded that few technically skilled employees can help organisations with the process of BIM adoption. This factor has also been recognised as the foremost obstacle in the path of BIM implementation in the US (Ku and Taiebat 2011) and one of the significant obstacles in the UK (Khosrowshahi and Arayici 2012) among the developed countries. Among the developing countries, the high cost of training and lack of trained professionals are ranked third and fifth according to significance in a study in the context of Nigeria (Abubakar et al. 2014). The high cost of training has also been recognised as a significant hurdle in BIM implementation in Malaysia (Sahil 2016) and China (Ying 2011).

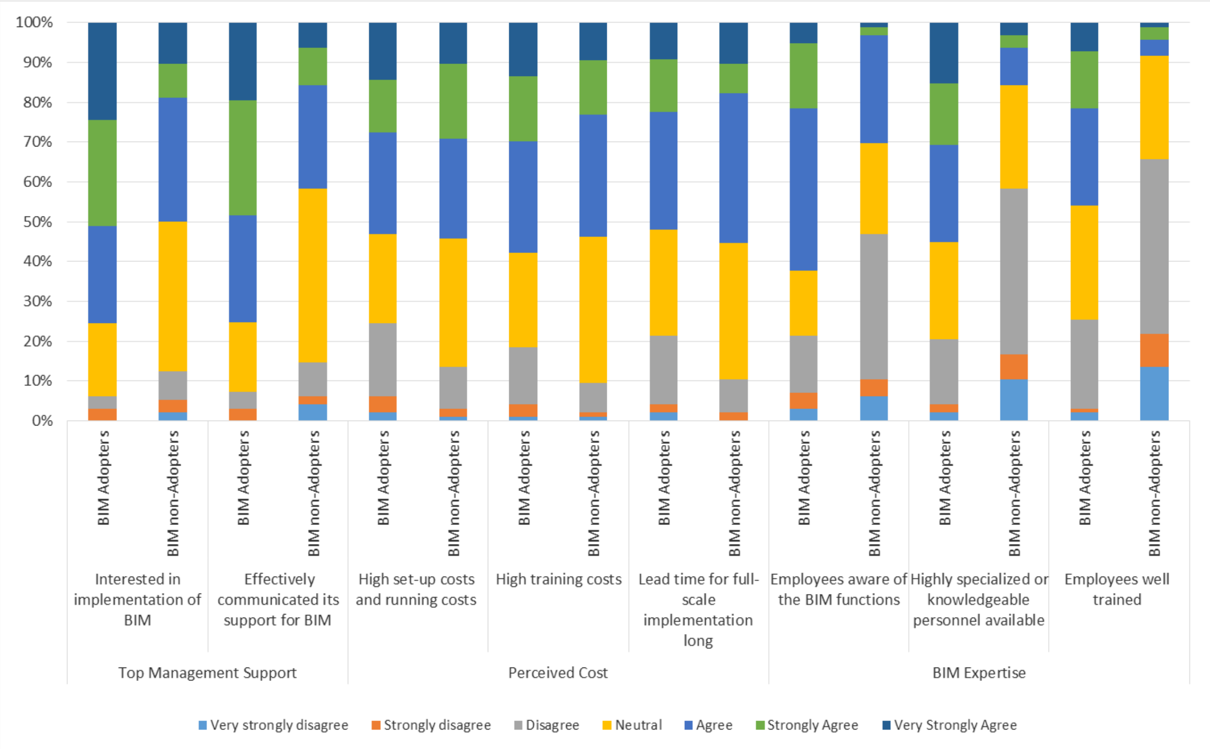

Figure 3: Organizational factors affecting BIM adoption decision

Environmental factors

Environmental factors considered in this study comprised of client requirements, trade partner readiness and regulatory support. Figure 4 shows that 44% of BIM adopters stated that BIM implementation in their organisations is mostly driven by request from sponsors whereas only 29% of the non-adopters believed that use of BIM would be asked for by sponsors. With the current status of BIM adoption and implementation in the industry, 31% of BIM adopters and 32% of non-adopters were unable to comment on this issue decisively.

The role of demand from the client’s side has been noted in the context of the UK (Khosrowshahi and Arayici 2012), and the role of contractual agreements in the USA (Ku and Taiebat 2011). In the context of developing countries, this has been noted in Nigeria (Abubakar et al. 2014) and Malaysia (Sahil 2016).

Another challenge faced by the architectural firms is that the engineering consultants possess limited knowledge regarding BIM leading to inefficient BIM adoption. Although 46% of adopters and 39% of non-adopters confirmed that project consultants are willing to implement BIM, 41% of adopters and 36% of non-adopters also reported that project consultants lack in technical knowledge regarding BIM.

Non–availability of government incentives for BIM adoption has been considered as another hurdle for effective BIM adoption in India. In countries like UK and Singapore, strong support by the government (Building and Construction Authority 2012; UKBIMA 2016) has been documented as one of the major drivers for encouraging and increasing the rate of BIM adoption. However, in this study, 51% of the BIM adopters reported that there are no incentives by the Indian government for BIM adoption, while 49% thought that current green rating systems can support BIM adoption. The contribution of BIM to green construction has been noted in other contexts (Autodesk 2005; Azhar et al. 2010; McGraw Hill Construction 2010; Becerik-Gerber et al. 2012).

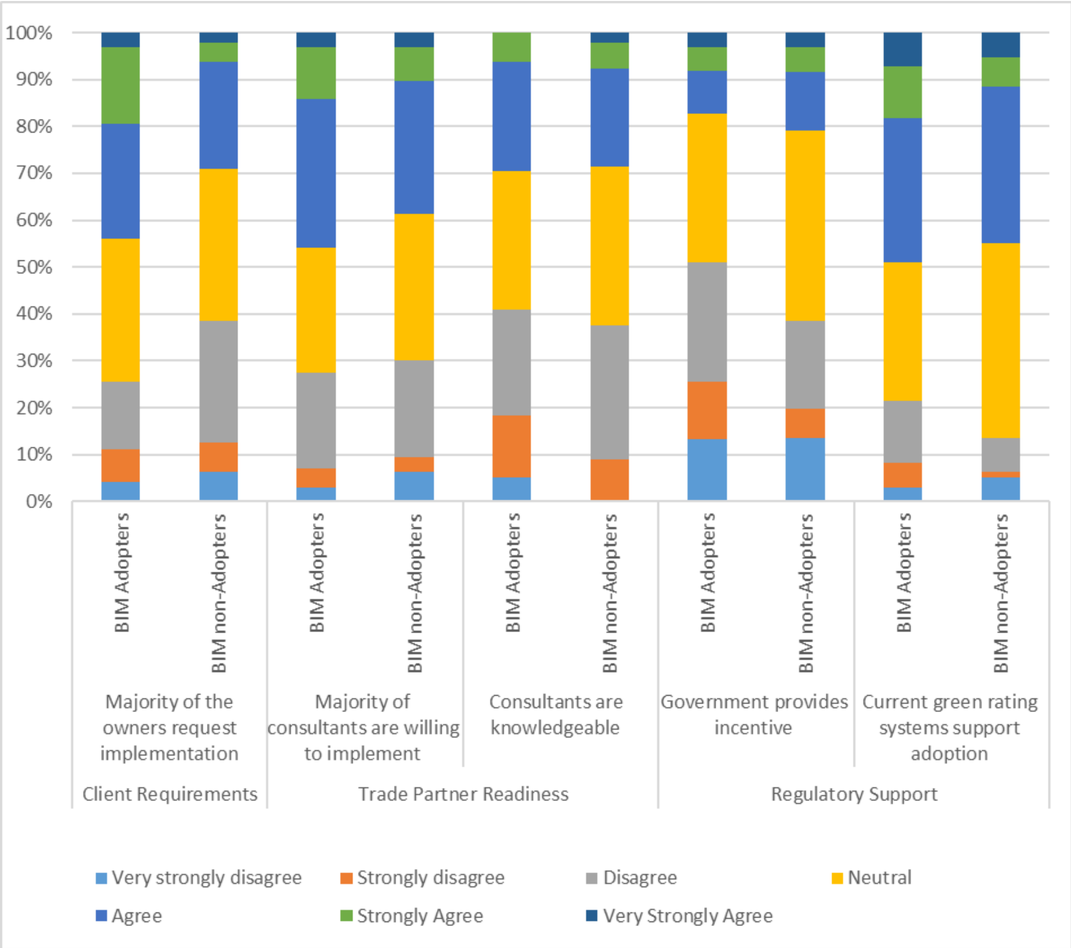

Figure 4: Environmental factors affecting BIM adoption decision

Impact of BIM on performance and trust

In considering the impact of BIM on performance and trust (refer Figure 5), 83% of BIM adopters and 69% of non-adopters believe that BIM has the potential to improve the quality of work within architectural firms. 81% BIM adopters and 69% non-adopters, were positive regarding improvement in the effectiveness of their work practices contributed by the implementation of BIM.

71% adopters and 63% non-adopters, were positive regarding the improvements in productivity caused by the implementation of BIM. Again, 75% of the BIM adopters and 64% of the non-adopters reported that BIM implementation has a positive impact on coordination of drawings and construction activities. BIM-related performance benefits and similar findings have also been documented globally in the works of Azhar (2011), Azhar et al. (2012), Barlish and Sullivan (2012), Chen and Luo (2014), Coates et al. (2010) Eastman et al. (2011) and Sebastian (2011).

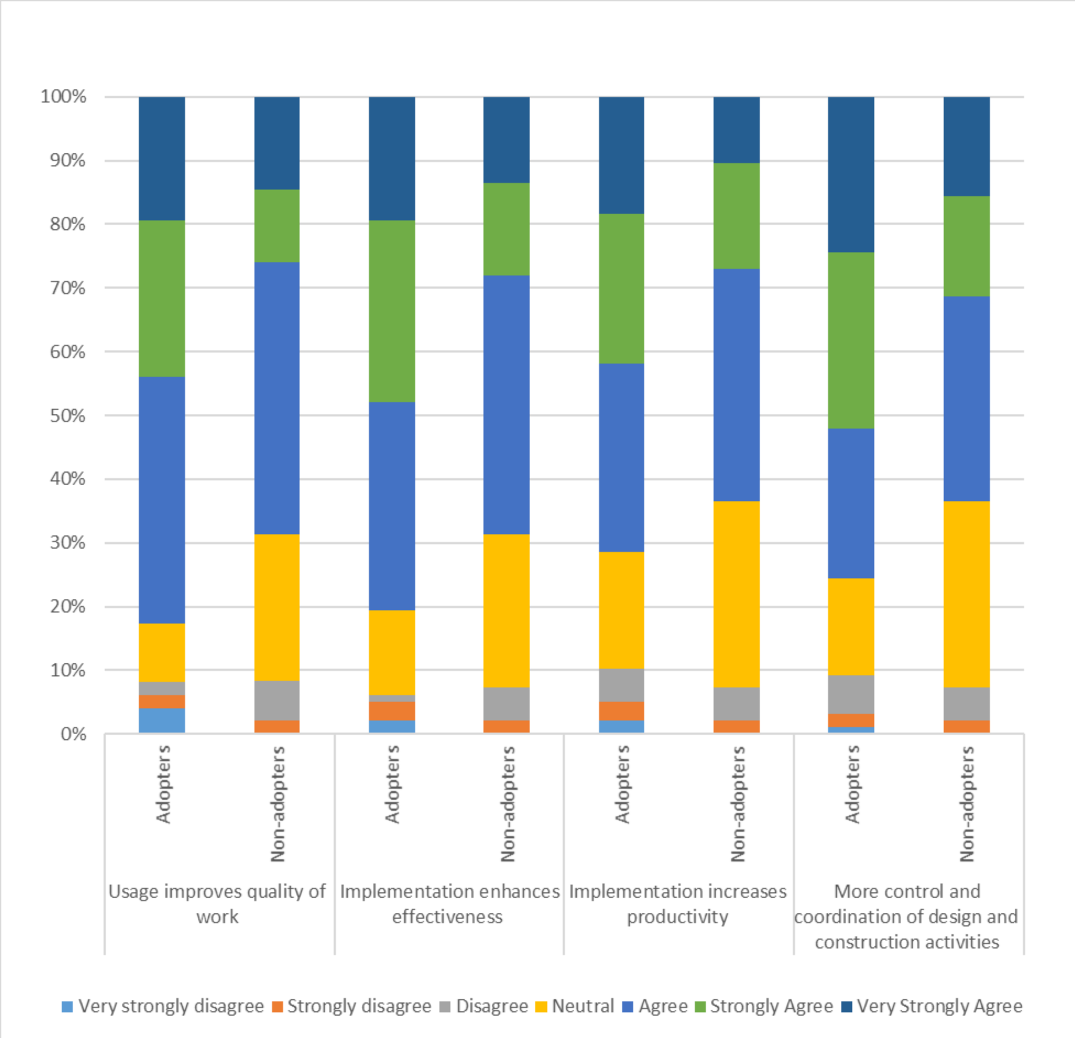

Figure 5: Impact of BIM on performance

From Figure 6, it is evident that BIM as a process is gaining the trust of architectural firms in India. 67% adopters and 51% non-adopters stated that the BIM process is trustworthy; while 69% adopters and 49% of non-adopters also believe that BIM process is reliable and that once implemented in projects, has either improved or can improve the effectiveness of work and efficiency in performance.

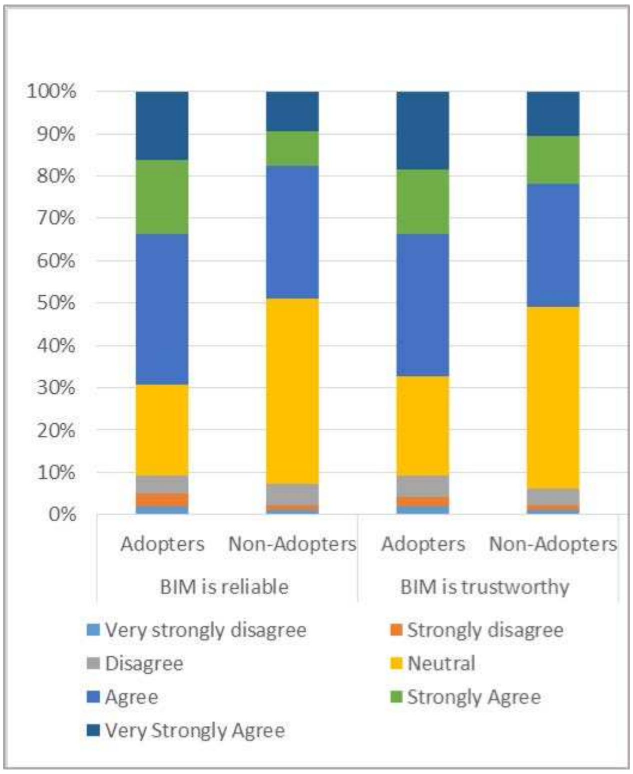

Figure 6: Impact of BIM on Trust

Conclusions

This study has found that the full potential of BIM has not yet been explored on Indian projects by architectural firms. Usage is still in an initial stage, judging from the description of the three stages in the literature (Succar 2010). Although there are some new players who are willing to use BIM on their projects, a number of challenges are being reported. From the questionnaire-survey that was conducted, the significant drivers of and barriers to BIM adoption, are categorized using the TOE framework and provided in Table 5 below.

Table 5: Inhibitors and drivers to BIM Implementation

1. Technological Factors	1.1 Inhibitors	a. Full potential of BIM is unclear
		b. BIM software is complex to use
		c. BIM implementation is a complex process
		d. Lack of process standardisation

	1.2. Drivers	a. Consistency with existing beliefs and values
		b. Availability of BIM software on trial basis
		c. Favourable attitude towards BIM
2. Organizational Factors	2.1. Inhibitors	a. High set up cost
		b. High training and running costs
		c. Lack of awareness
		d. Long lead time required for full-scale implementation
		e. Non-availability of BIM expertise
	2.2. Drivers	a. Compatibility with existing beliefs, values
		b. Top Management support
3. Environmental factors	3.1. Inhibitors	a. Lack of government incentives
		b. Lack of BIM knowledge within project
		c. Clients do not require BIM
	3.2. Drivers	a. BIM readiness by project consultants
		b. Existing green rating system supporting BIM

Looking at the challenges, it is inferred that development of a BIM implementation plan and an organizational framework for AEC industry in India is needed for the improved usage of BIM in the sector. This would aid in several ways such as providing guidelines to adopt BIM (points 1.1b and 1.1c of Table 4), suggesting some standardisation in the process of implementation (points 1.1d of Table 4), spreading awareness, clarifying the BIM-related processes and increasing top management support (points 2.1c, 1.1a and 2.2b of Table 4). The guidelines would also bring about clarity among clients (point 3.1c of Table 3) and among the stakeholders on their respective responsibilities in a BIM-integrated work-structure (points 3.1b and 3.2a on Table 4). BIM is a collaborative system, and without synergy of all the consultants, such a complex mechanism cannot be handled successfully. The necessity of BIM-capability amongst all the stakeholders for its full utilisation has been also been identified in the context of USA (Ku and Taiebat 2011), China (Zhang 2011) and Malaysia (Zahrizan et al. 2014).

The hindrance caused by the complexity involved in BIM adoption is also noted in other developing countries like China (Ma 2013; Wang et al. 2016). Government-support and encouragement have been suggested for other developing countries, like Brazil (Kassem 2016). The Building and Construction Authority of Singapore has recommended that the public sector has to take the lead in BIM adoption, along with regulatory approval, incentives, capability-development and removal of impediments (Building and Construction Authority 2012).

An implementation strategy will also hopefully create an incentive from the government for development of expertise in BIM (points 3.1a and 2.1e of Table 4). BIM-education could be incorporated as a part of existing civil engineering, architecture and allied streams, empowering more professionals to be qualified to handle BIM-integrated construction projects (points 2.1a, 2.1b, 2.1e, 3.1b and 3.2a in Table 4). The absolute necessity of a mature form of BIM training is recognised in a study in Brazil (Kassem 2016), while a study in the context of Singapore suggests the introduction of more widespread undergraduate and postgraduate course-modules focused on BIM (Attarzadeh et al. 2015). The respondents also note that greater incentives of green ratings can promote BIM. A national BIM education and research agenda can ensure the creation of a well-defined organisational BIM framework. Further studies and learnings from mature BIM markets can also help Indian AEC industry to develop BIM implementation strategies.

References

Abubakar M, Ibrahim YM, Kado D, Bala K. 2014. Contractors' Perception of the Factors Affecting Building Information Modelling (BIM) Adoption in the Nigerian Construction Industry. In: Computing in Civil and Building Engineering (2014). Reston, VA, VA: American Society of Civil Engineers. p. 167–178.

Ajzen I. 1991. The theory of planned behavior. Organ. Behav. Hum. Decis. Process. 50:179–211. doi:10.1016/0749-5978(91)90020-T.

Al-qirim NA. 2007. E-Commerce Adoption in Small Businesses : Cases from New Zealand. J. Inf. Technol. Case Appl. Res. 9:28–57.

Arayici Y, Coates P, Koskela L, Kagioglou M, Usher C, O'Reilly K. 2011. Technology adoption in the BIM implementation for lean architectural practice. Autom. Constr. 20:189–195. doi:10.1016/j.autcon.2010.09.016.

Attarzadeh M, Nath T, Tiong RLK. 2015. Identifying key factors for building information modelling adoption in Singapore. Proc. Inst. Civ. Eng. - Manag. Procure. Law 168:220–231. doi:10.1680/jmapl.15.00030.

Autodesk. 2005. Building Information Modeling for Sustainable Design. Autodesk:1–13.

Azhar S. 2011. Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry. Leadersh. Manag. Eng. 11:241–252. doi:10.1061/(ASCE)LM.1943-5630.0000127.

Azhar S, Brown JW, Sattineni A. 2010. A case study of building performance analyses using building information modeling. In: 2010 - 27th International Symposium on Automation and Robotics in Construction, ISARC 2010. IAARC. p. 213–222.

Azhar S, Khalfan M, Maqsood T. 2012. Building information modeling (BIM): now and beyond. Australas. J. Constr. Econ. Build. 12:15–28.

Balocco R, Mogre R, Toletti G. 2009. Mobile internet and SMEs: a focus on the adoption. Ind. Manag. Data Syst. 109:245–261. doi:10.1108/02635570910930127.

Bandura A, Cervone D. 1986. Differential engagement of self-reactive influences in cognitive motivation. Organ. Behav. Hum. Decis. Process. 38:92–113. doi:10.1016/0749-5978(86)90028-2.

Barlish K, Sullivan K. 2012. How to measure the benefits of BIM — A case study approach. Autom. Constr. 24:149–159. doi:10.1016/j.autcon.2012.02.008.

Becerik-Gerber B, Jazizadeh F, Li N, Calis G. 2012. Application Areas and Data Requirements for BIM-Enabled Facilities Management. J. Constr. Eng. Manag. 138:431–442. doi:10.1061/(ASCE)CO.1943-7862.0000433.

Bouchbout K, Alimazighi Z. 2008. A Framework for Identifying the Critical Factors Affecting the Decision to Adopt and Use Inter-Organizational Information Systems. In: Proceedings of World Academy of Science: Engineering & Technology (2008). Vol. 2. p. 338–345.

Building and Construction Authority S. 2012. Singapore BIM Guide.

Cao D, Wang G, Li H, Skitmore M, Huang T, Zhang W. 2015. Practices and effectiveness of building information modelling in construction projects in China. Autom. Constr. 49:113–122. doi:10.1016/j.autcon.2014.10.014.

Chen L, Luo H. 2014. A BIM-based construction quality management model and its applications. Autom. Constr. 46:64–73. doi:10.1016/j.autcon.2014.05.009.

Chew A, Riley M. 2013. What Is Going on With Bim ? on the Way To 6D. Int. Constr. Law Rev. 30:253–265.

Chiyangwa TB, (Trish) Alexander PM. 2016. Rapidly co-evolving technology adoption and diffusion models. Telemat. Informatics 33:56–76. doi:10.1016/j.tele.2015.05.004.

Coates P, Arayici Y, Koskela K, Kagioglou M, Usher C, O'Reilly K. 2010. The key performance indicators of the BIM implementation process. Practice:6.

Compeau DR, Higgins CA. 1995. Computer Self-Efficacy: Development of a Measure and Initial Test. MIS Q. 19:189. doi:10.2307/249688.

Council of Architecture. 2017. Council of Architecture.

Crook CW, Kumar RL. 1998. Electronic data interchange: a multi-industry investigation using grounded theory. Inf. Manag. 34:75–89. doi:10.1016/S0378-7206(98)00040-8.

Dasgupta S, Agarwal D, Ioannidis A, Gopalakrishnan S. 1999. Determinants of Information Technology Adoption: An Extension of Existing Models to Firms in a Developing Country. J. Glob. Inf. Manag. 7:30.

Davis FD. 1989. Perceived Usefulness, Perceived Ease Of Use, And User Accep. MIS Quarterly; Sep 13.

Davis FD, Bagozzi RP, Warshaw PR. 1992. Extrinsic and Intrinsic Motivation to Use Computers in the Workplace1. J. Appl. Soc. Psychol. 22:1111–1132. doi:10.1111/j.1559-1816.1992.tb00945.x.

Deligiannaki A, Ali M. 2011. Cross-cultural influence on diffusion and adoption of innovation: An exploratory case study to investigate the social-cultural barriers.

Department of Policy & Promotion. Make In India.

Doloi H, Sawhney A, Iyer KC. 2012. Structural equation model for investigating factors affecting delay in Indian construction projects. Constr. Manag. Econ. 30:869–884. doi:10.1080/01446193.2012.717705.

Doolin B, Al Haj Ali E. 2008. Adoption of Mobile Technology in the Supply Chain. Int. J. E-bus. Res. 4:1–15. doi:10.4018/jebr.2008100101.

Eastman C, Teicholz P, Sacks R, Liston K. 2011. BIM handbook: A guide to building information modeling for Owners, Managers, Designers, Engineers and Contractors.

Elmualim A, Gilder J. 2014. BIM: innovation in design management, influence and challenges of implementation. Archit. Eng. Des. Manag. 10:183–199. doi:10.1080/17452007.2013.821399.

Fishbein M, Ajzen I. 1975. Belief, Attitude, Intention, and Behavior: An Introduction to Theory and Research. Reading, MA: Addison-Wesley.

Gefen D, Straub DW. 1997. Gender Differences in the Perception and Use of E-Mail: An Extension to the Technology Acceptance Model. Source MIS Q. 21:389–400.

Geng DL. 2011. Strategy and analysis on BIM applications. J. Inf. Technol. Civ. Eng. Archit.:51–54.

Gong YX. 2012. Analysed the present situation of the application of BIM in our country and the development obstacles. Electron. Commer.:204–205.

Grover V. 1993. An Empirically Derived Model for the Adoption of Customer-based Interorganizational Systems. Decis. Sci. 24:603–640. doi:10.1111/j.1540-5915.1993.tb01295.x.

Gu N, London K. 2010. Understanding and facilitating BIM adoption in the AEC industry. Autom. Constr. 19:988–999. doi:10.1016/j.autcon.2010.09.002.

Howard R, Björk B-C. 2008. Building information modelling – Experts' views on standardisation and industry deployment. Adv. Eng. Informatics 22:271–280. doi:10.1016/j.aei.2007.03.001. [accessed 2015 Aug 9]. http://www.sciencedirect.com/science/article/pii/S1474034607000201.

Hsu P-F, Kraemer K, Dunkle D. 2006. Determinants of E-Business Use in U.S. Firms. Int. J. Electron. Commer. 10:9–45. doi:10.2753/JEC1086-4415100401.

Huang Z, Janz BD, Frolick MN. 2008. A Comprehensive Examination of Internet-EDI Adoption. Inf. Syst. Manag. 25:273–286. doi:10.1080/10580530802151228.

Jain M, Nhat A, Le H, Lin JY, Cheng JM. 2011. Exploring the Factors Favoring mCommerce Adoption among Indian MSMEs : A TOE Perspective. Tunghai Manag. Rev. 13:147–188.

Kassem M. 2016. Mohamad Kassem : " Strategy for the diffusion of BIM in Brazil ." MakeBIM:1–25.

Kaur Kapoor K, K. Dwivedi Y, D. Williams M. 2014. Innovation adoption attributes: a review and synthesis of research findings. Eur. J. Innov. Manag. 17:327–348. doi:10.1108/EJIM-08-2012-0083.

Khosrowshahi F, Arayici Y. 2012. Roadmap for implementation of BIM in the UK construction industry. Eng. Constr. Archit. Manag. 19:610–635. doi:10.1108/09699981211277531.

Ku K, Taiebat M. 2011. BIM Experiences and Expectations: The Constructors' Perspective. Int. J. Constr. Educ. Res. 7:175–197. doi:10.1080/15578771.2010.544155.

Kuan KKY, Chau PYK. 2001. A perception-based model for EDI adoption in small businesses using a technology-organization-environment framework. Inf. Manag. 38:507–521. doi:10.1016/S0378-7206(01)00073-8.

Kumar S, Swaminathan JM. 2003. Diffusion of Innovations Under Supply Constraints. Oper. Res. 51:866–879. doi:10.1287/opre.51.6.866.24918.

Kunz J, Fischer M. 2012. Virtual Design and Construction: Themes, Case Studies and Implementation Suggestions.

Leonard-Barton D, Deschamps I. 1988. Managerial Influence in the Implementation of New Technology. Manage. Sci. 34:1252–1265. doi:10.1287/mnsc.34.10.1252.

Lin H-F, Lin S-M. 2008. Determinants of e-business diffusion: A test of the technology diffusion perspective. Technovation 28:135–145. doi:10.1016/j.technovation.2007.10.003.

Lin H-F, Lin SM. 2008. Determinants of e-business diffusion: A test of the technology diffusion perspective. Technovation 28:135–145. doi:10.1016/j.technovation.2007.10.003.

Lin H, Lee G. 2005. Impact of organizational learning and knowledge management factors on e-business adoption. Manag. Decis. 43:171–188. doi:10.1108/00251740510581902.

Linderoth HCJ. 2010. Understanding adoption and use of BIM as the creation of actor networks. Autom. Constr. 19:66–72. doi:10.1016/j.autcon.2009.09.003.

Ma ZL. 2013. China's construction industry status, problems and countermeasures of application of BIM technology. China Surv. Des.:29–42.

Mcauley B, Hore A V, Deeney J, Hore A. 2013. Public / Private BIM: An Irish Perspective CITA BIM Public / Private BIM: An Irish Perspective. :14–15.

McGraw Hill Construction. 2010. Green BIM: How Building Information Modelling is Contributing to Green Design and Construction.

McGraw Hill Construction. 2014. The Business Value of BIM for Owners.

Mirchandani AA, Motwani J. 2001. Understanding Small Business Electronic Commerce Adoption: An Empirical Analysis. J. Comput. Inf. Syst. 41:70–73. doi:10.1080/08874417.2001.11647011.

NATSPEC. 2011. National BIM Guide v1.0.

Navendren D, Manu P, Shelbourn M, Mahamadu A. 2014. Challenges to building information modelling implementation in UK: Designers' perspectives. Raiden A, Aboagye-Nimo E, editors. Raiden, A. Aboagye-Nimo, E., eds. Proc. 30th Annu. ARCOM Conf. Portsmouth, 1-3 Sept. 2014. UK Assoc. Res. Constr. Manag.:733–742. doi:10.13140/2.1.1093.5685.

NBS. 2016. NBS International BIM Report 2016. Newcastle Upon Tyne.

NBS. 2017. National BIM Report 2017. Newcastle Upon Tyne.

Newton K, Chileshe N. 2012. Awareness , Usage and Benefits of Building Information Modelling (BIM) Adoption – the Case of the South Australian Construction Organisations. Procs 28th Annu. ARCOM Conf.:3–12. doi:10.13140/RG.2.1.2352.3363.

OECD. 2017. OECD Economic Surveys: India.

Oliveira T, Martins, M F. 2011. Literature Review of Information Technology Adoption Models at Firm Level. Electron. J. Inf. Syst. Eval. 14:110–121.

Oxford Economics. 2016. Global Construction 2030. London.

Panuwatwanich K, Peansupap V. 2013. Factors affecting the current diffusion of BIM: a qualitative study of online professional network. Creat. Constr. Conf. Budapest, Hungary:575–586. doi:http://hdl.handle.net/10072/53328.

Planning Commision. 2011. Faster, Sustainable and More Inclusive Growth - An Approach to Twelfth Five Year Plan.

Planning Commission. 2013. Twelfth Five Year Plan (2012–2017) Economic Sectors, Vol II. :362–373.

Podsakoff PM, MacKenzie SB, Lee J-Y, Podsakoff NP. 2003. Common method biases in behavioral research: A critical review of the literature and recommended remedies. J. Appl. Psychol. 88:879–903. doi:10.1037/0021-9010.88.5.879.

Premkumar G, Roberts M. 1999. Adoption of new information technologies in rural small businesses. Omega 27:467–484. doi:10.1016/S0305-0483(98)00071-1.

Ramdani B, Kawalek P, Lorenzo O. 2009. Predicting SMEs' adoption of enterprise systems. Dwivedi YK, editor. J. Enterp. Inf. Manag. 22:10–24. doi:10.1108/17410390910922796.

Ramilo R, Embi MR Bin. 2014. Critical analysis of key determinants and barriers to digital innovation adoption among architectural organizations. Front. Archit. Res. 3:431–451. doi:10.1016/j.foar.2014.06.005.

Roberts KG, Pick JB. 2004a. Technology factors in corporate adoption of mobile cell phones: a case study analysis. In: 37th Annual Hawaii International Conference on System Sciences, 2004. Proceedings of the. IEEE. p. 10 pp.

Roberts KG, Pick JB. 2004b. Technology factors in corporate adoption of mobile cell phones: a case study analysis. In: 37th Annual Hawaii International Conference on System Sciences, 2004. Proceedings of the. Vol. 0. IEEE. p. 10 pp.

Roberts KG, Pick JB. 2004. Technology factors in corporate adoption of mobile cell phones: a case study analysis. Syst. Sci. 2004. Proc. 37th Annu. Hawaii Int. Conf. 0:10 pp.-pp. doi:10.1109/HICSS.2004.1265678.

Rogers E, Shoemaker F. 1971. Communication of innovations: a cross-cultural approach. New York Free Press 1971.

Rogers EM. 2003. Diffusion of Innovations. New York: The Free Press.

Sahil A. 2016. Adoption of Building Information Modeling in Developing Countries : Colorado State University. Libraries.

Sawhney A. 2014a. International BIM implementation guide: RICS guidance note, global. 1st ed. London: Royal Institution of Chartered Surveyors.

Sawhney A. 2014b. State of BIM Adoption and Outlook in India.

Sawhney A, Agnihotri R, Kumar Paul V. 2014. Grand challenges for the Indian construction industry. Florence Yean Yng Ling and Dr Carlo D, editor. Built Environ. Proj. Asset Manag. 4:317–334. doi:10.1108/BEPAM-10-2013-0055.

Sawhney A, Singh MM, Ahuja R. 2017. Wordwide BIM Overview. In: Wu P, Li H, Wang X, editors. Integrated Building Information Modelling. BENTHAM SCIENCE PUBLISHERS. p. 1–45.

Sebastian R. 2011. Changing roles of the clients, architects and contractors through BIM. Eng. Constr. Archit. Manag. 18:176–187. doi:10.1108/09699981111111148.

Sharma R, Mishra R. 2014. A Review of Evolution of Theories and Models of Technology Adoption. Managing 6:44. doi:10.9790/487X-1810063748.

Soon CB, Gutiérrez JA. 2003. Effects of the RFID Mandate on Supply Chain Management. J. Theor. Appl. Electron. Commer. Res. 3:81–91.

Succar B. 2010. Building Information Modelling Maturity Matrix. In: Concepts and Technologies. p. 65–103.

Thompson RL, Higgins CA, Howell JM. 1991. Personal Computing: Toward a Conceptual Model of Utilization. MIS Q. 15:125. doi:10.2307/249443.

Tornatzky LG, Fleischer M, Chakrabarti AK. 1990. The processes of technological innovation. Lexington Mass.: Lexington Books.

UKBIMA. 2016. BIM in the UK : Past , Present & Future.

Venkatesh V, Sykes TA, Venkatraman S. 2014. Understanding e-Government portal use in rural India: role of demographic and personality characteristics. Inf. Syst. J. 24:249–269. doi:10.1111/isj.12008.

Vidakovic B. 2014. Margin of Error. In: Wiley StatsRef: Statistics Reference Online. Chichester, UK, UK: John Wiley & Sons, Ltd.

Wang G, Liu Z, Wang H. 2016. Key Factors Affecting BIM Adoption in China Based on

TOE & RC. In: International Conference on Mechanics, Materials and Structural Engineering (ICMMSE 2016). p. 103–108.

Won J, Lee G, Dossick C, Messner J. 2013. Where to Focus for Successful Adoption of Building Information Modeling within Organization. J. Constr. Eng. Manag. 139:4013014. doi:10.1061/(ASCE)CO.1943-7862.0000731.

Xu H, Feng J, Li S. 2014. Users-orientated evaluation of building information model in the Chinese construction industry. Autom. Constr. 39:32–46. doi:10.1016/j.autcon.2013.12.004. [accessed 2015 Apr 28]. http://www.sciencedirect.com/science/article/pii/S0926580513002161.

Xu S, Zhu K, Gibbs J. 2004. Global Technology, Local Adoption: A Cross-Country Investigation of Internet Adoption by Companies in the United States and China. Electron. Mark. 14:13–24. doi:10.1080/1019678042000175261.

Xu, Feng J, Li S. 2014. Users-orientated evaluation of building information model in the Chinese construction industry. Autom. Constr. 39:32–46. doi:10.1016/j.autcon.2013.12.004.

Yan H, Damian P. 2008. Benefits and Barriers of Building Information Modelling. In: Proc. of 12th International Conference on Computing in Civil and Building Engineering.

Ying YK. 2011. What kind of career environment for talent plus development-The consulting team and talent plus one of BIM thinking. J. Inf. Technol. Civ. Eng. Archit.:37–39.

Zahrizan Z, Ali M, Haron T, Marshall-ponting A. 2014. Summary for Policymakers. In: Intergovernmental Panel on Climate Change, editor. Climate Change 2013 - The Physical Science Basis. Vol. 75. Cambridge: Cambridge University Press. p. 1–30.

Zhang CX. 2011. BIM technology application situation and development of the construction industry in our country obstacles to study. Build. Econ.:96–98.

Zhu K, Kraemer K, Xu S. 2003. Electronic business adoption by European firms: a cross-country assessment of the facilitators and inhibitors. Eur. J. Inf. Syst. 12:251–268. doi:10.1057/palgrave.ejis.3000475.

Zhu K, Kraemer KL. 2005. Post-Adoption Variations in Usage and Value of E-Business by Organizations: Cross-Country Evidence from the Retail Industry. Inf. Syst. Res. 16:61–84. doi:10.1287/isre.1050.0045.