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Profound barriers to building information modelling (BIM) adoption in construction small and medium-sized enterprises (SMEs)

An interpretive structural modelling approach

Received 9 September 2019
Revised 31 December 2019
Accepted 23 January 2020

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Abstract

Purpose – This study aims to evaluate and investigate the dynamics of the barriers to building information modelling (BIM) adoption from the perspective of small and medium-sized enterprises (SMEs) in developing countries with the Nigerian construction industry as a case study.

Design/methodology/approach – An interpretive structural modelling approach was adopted to develop a hierarchical model of the interrelationships of the barriers. Also, the Matrice d'Impacts croises-multipication applique a classement analysis was used for categorisation of the barriers.

Findings – The findings revealed that the barriers are from a sociotechnical context and that SMEs have the will to drive BIM adoption by focussing more on their internal environment.

Originality/value – This study presented the adoption of BIM in SMEs, which is underrepresented in extant studies. Also, it contributes to the nascent discussion of BIM from the perspective of SMEs in developing countries.

Keywords Construction management, BIM, SMEs, Information systems/management, Construction technology, IT management

Paper type Research paper

Background of study

The Nigerian architecture, engineering and construction (AEC) industry is the biggest in West Africa and is a prime source of employment for the skilled, semiskilled and unskilled workforce in the country (Danwata, 2017). The sector is very important as it has the capacity to lead the economy of Nigeria (Oladinrin *et al.*, 2012) and has strong linkages to other sectors of the economy. It is a notable vehicle for the infrastructural and industrial development of Nigeria (Ayodele and Alabi, 2011). It contributed 3.2 per cent to the real GDP in 2017 and provides products and services for virtually all other industries to carry out their operation (Dantata, 2007). The Nigerian AEC industry like others in similar developing countries is made up of both small and medium-sized enterprises (SMEs) and large firms.

This research study is fully supported through funding of the full-time PhD research studentship under the auspice of the Department of Building and Real Estate, The Hong Kong Polytechnic University, Hong Kong. Special thanks are extended to the experts who have participated in the survey. Also, the authors are grateful to the editor, and the anonymous reviewers whose constructive comments and suggestions have significantly helped in improving the quality of this paper.

1471-4175
DOI 10.1108/CI-09-2019-0087

The SMEs category consists of enterprises with less than 200 employees and less than ₦500m annual turnover, while the large firms consist of 200 or more employees and more than ₦500m turnover (SMEDAN, 2005).

The SME category consists majorly of indigenous firms and is the backbone of the Nigerian AEC. Despite the innate potentials of the Nigerian AEC, the sector is underperforming and hindered by many challenges, which have affected its capacity to deliver effectively, efficiently and achieve value for money (Saka *et al.*, 2019f). Harbingers of the problem are project abandonment, cost overrun, time overrun, stakeholders conflict and waste, which has led to the sector being tagged as a "sleeping giant" (Kolo and Ibrahim, 2010). The problems facing the Nigerian AEC are compounded by the fragmented nature of the industry, an increase in the number of stakeholders, lack of information management and the traditional approach. Consequently, there have been calls for the need to change the traditional approach of the AEC and to leverage on information, technology and communication (ICT) tools as done in developed countries. Oyediran and Odusami (2005) assessed the usage of ICT by the Nigerian quantity surveyors and revealed that about 90 per cent of the professionals have been using it for project cost management services. Similarly, Oladapo (2006) assess the proliferation and impact of ICT on professional practice in the industry. The study concluded that there is a high acceptance rate and the impacts of ICT usage are cost-saving, quick decision making and efficiency. Oladapo (2007) examined the factors impacting the ICT usage in the industry and revealed that the internal environmental factors have a significant impact on the usage.

With the advent of building information modelling (BIM), AEC industries in developed countries have been changing their mode of operation and reaping concomitant benefits (Chan *et al.*, 2019b). Kori and Kiviniemi (2015) opined that it is imperative for the Nigerian AEC to exploit the BIM benefits to improve its performance. Ibrahim and Bishir (2012) corroborated that BIM has the potential to "bring about the total change required in the sector". Munir and Jeffrey (2013) presented a summary of UK BIM experience and drew lessons for the implementation in the Nigeria AEC industry. However, much has not been reported as regards BIM adoption and implementation in Nigeria and in Africa as a whole (Olawumi and Chan, 2019b; Saka and Chan, 2019a). Thus, it is referred to as BIM infant industry like most developing countries (Jayasena and Weddikkara, 2013).

Over the years, there have been studies (Amuda-Yusuf *et al.*, 2018; Olugboyega and Aina, 2016) on BIM awareness in Nigeria. These revealed that the level of awareness is increasing albeit at a slow pace and there is still a lack of clear understanding of BIM in Nigeria (Ogunmakinde and Umeh, 2018). Saka *et al.* (2019d) reviewed the few extant kinds of literature in the Nigerian AEC and concluded that the major focus has been on awareness of BIM and little has been done on BIM implementation. It revealed the lack of studies on BIM in SMEs, which are the backbone of the sector and represent the major percentage of the firms. The emerging trend is the underrepresentation of the SMEs and the extant studies do not focus on this important category. Amuda-Yusuf (2018) asserted that the size of the firm influences the level of awareness and BIM usage in the Nigerian AEC. Thus, Kori *et al.* (2019) concluded that the level of awareness and usage in small firms is very low and lagging that of large firms in Nigeria.

There is a growing body of literature that recognises the importance of BIM in SMEs, although these are from developed countries with a high level of BIM awareness and government support. Sexton *et al.* (2006) underscore the importance of innovation in small firms and the need to adopt different views in approaching SMEs and large firms as they are different. Dainty *et al.* (2017) opined that the adoption of BIM in SMEs is a necessity for the proliferation of BIM in the AEC and studies of BIM in SMEs are of global importance as the

SMEs would continue to dominate the AEC (Shelton *et al.*, 2016). Similarly, Hillebrandt (2006) averred that there is a need to focus on SMEs because a small increase in the productivity of SMEs would have an influential effect on the AEC. A singular view of both SMEs and large firms has been said not to be realistic because the SMEs and large firms would react differently to the same business situations. Gledson *et al.* (2012) concluded that there are differences in the perception of BIM between SMEs and large firms (Aranda-Mena *et al.*, 2008).

As there are dominant assumptions that BIM is always beneficial and tends to be viewed in unreflective light. This hampers an appreciation that BIM is associated with uncertainty and barriers (Chan *et al.*, 2019a). Thus, this paper aims to identify the dynamic and relationship between the barriers affecting the BIM adoption in SMEs of developing countries with Nigeria as a case study. This is because these challenges are greater in developing countries AEC (Migilinskas *et al.*, 2013; Saka *et al.*, 2019e) with a low level of awareness and little or no government support. It is thus imperative to study the barriers hindering BIM from the SME's perspective (Shelton *et al.*, 2016) with the motive of finding a means to overcome the barriers. Identification of the dynamics of these barriers is a step towards the proliferation of BIM in the AEC as the SMEs are the backbone. Sustainable adoption of BIM in SMEs would no longer be a necessity but unavoidable for SMEs to be competitive and to survive in the industry. This study would contribute to the few extant studies on BIM in SMEs and most importantly to the nascent discourse of BIM in SMEs from developing countries perspective where the SMEs are more significant and vital for development (Pandya, 2012; Saka *et al.*, 2019e).

Building information modelling adoption in small and medium-sized enterprises

McGraw Hill (2014) revealed that the majority of non-adopters of BIM are the SMEs, this could be related to the perception that they do not have sufficient resources and capability to adopt innovations such as BIM (Rodgers *et al.*, 2016). Olatunji (2011) corroborated that the cost of implementation of BIM, which includes the cost of software, training, hardware, training and services could be as high as $14,000 for a one system SME, which is a huge investment. This high initial investment may not be proportional to the immediate benefits accrued by the SMEs as these benefits might be intangible (Ghaffarianhoseini *et al.*, 2016b).

Bataw *et al.* (2014) reported the major barriers of adopting BIM in the UK SMEs are lack of government support, lack of BIM knowledge, lack of stakeholders' awareness and the high cost of implementation. The high cost of implementation, interoperability and lack of in-house skills are also highlighted by Ayinla and Adamu (2018) and Vidalakis *et al.* (2019) as factors impeding the SMEs in the UK. Thus, Ghaffarianhoseini *et al.* (2016b) reported that almost 75 per cent of the SMEs in the UK are nonadopters of BIM. Newton and Chileshe (2012) concluded that the SMEs are struggling with BIM adoption in the Australian AEC. Hosseini *et al.* (2016b) identified a lack of supply chain buy-in, lack of client demand and the high cost of implementation, which is in tandem with Hong *et al.* (2018). However, Hosseini *et al.* (2016a) averred that lack of knowledge is no longer the major barrier of SMEs in a developed country like Australia but the risk associated with investment in BIM is perceived as the major barrier. Bosch-Sijtsema *et al.* (2017) revealed that the major obstacles of Swedish medium-sized contractors are lack of clients' demand and internal demand in the company. It is well-established in the extant studies that the SMEs are facing numerous challenges, which might vary depending on the context such as the size of the SMEs, location and position on the supply chain (Hong *et al.*, 2019; Migilinskas *et al.*, 2013; Vidalakis *et al.*, 2019).

Ironically, SMEs are said to have the potentials to benefit more from BIM adoption than large firms because of their features. The small size of the projects and the short duration make higher implementation drive easier. Also, the organic and flexible structure of the SMEs and the fewer number of employees would make BIM adoption easy (Arayici *et al.*, 2011; Hong *et al.*, 2016). Studies (Chan *et al.*, 2019b; Poirier *et al.*, 2015a; Poirier *et al.*, 2015b, 2015c) have asserted that the SMEs stand to benefit from the adoption of BIM in their work practices. The adoption of BIM in SMEs would enable SMEs to compete and to survive the advent of technology change in the AEC.

Theoretical insights

Theoretical lenses of innovation diffusion theory (IDT), institutional theory (INT) and technology-organisation-environment (TOE) framework were adopted for a social and technical view. This view of BIM would enable drawing from both the internal and external environment. Cao *et al.* (2014) added that this view would enable BIM to be view as not only motivated by proactive efficiency but also by institutional forces. Similarly, Coates *et al.* (2010) opined that the sociotechnical view of BIM implementation does not only consider the implementation of technology but also considers the socio-cultural environments that provide the context for the implementation. Panuwatwanich and Peansupap (2013) concluded that understanding of BIM diffusion requires the examination of the internal, external environment and innovation characteristics. Thus, BIM innovation is institutional and organisational in nature (Davies and Harty, 2013). The IDT has been adopted to conceptualise BIM as a technological innovation in many extant studies (Hosseini *et al.*, 2016a). However, this theory has been criticised majorly for its focus on technology characteristics and less focus on the organisational and environmental factors in technology adoption. INT, on the other hand, provides room for additional understanding of innovation diffusion from the contextual lens of institutional logics (Papadonikolaki, 2017). It emphasise the roles of institutional forces in driving change in organisations (DiMaggio and Powell, 1983). The institutional isomorphism adopted consists of three isomorphic pressures, which are the coercive, normative and the mimetic forces. The TOE framework is an organisational level theory and part of Tornatzky *et al.* (1990) work. The framework presents the contexts that influence technology adoption as technology context, organisation context and environmental context. Adopting these lenses enables building on theories that are closely interwoven and built on a robust body of knowledge from sociology, psychology and communications (Kale and Arditi, 2005). Also, neglecting theories in innovation studies might result in overlooking many aspects of innovation in any field including construction (Hosseini *et al.*, 2015).

Research method

The research method consists of three phases as depicted in Figure 1:

(1) *Phase I*: Identifying major barriers to BIM in SMEs: this involves a detailed review of extant BIM studies to identify the barriers to BIM in SMEs. A combination of different databases (Scopus, Web of Science and Google Scholar) was used to have wider coverage. The Scopus has a wider coverage (Saka and Chan, 2019c) while the Web of Science consists of "important journals". All publications were considered to avoid publication bias and because the study of BIM in SMEs is still in its nascent stage and has not gained wide coverage. Citation tracking was also used to the point of "critical saturation" (Randolph, 2009).

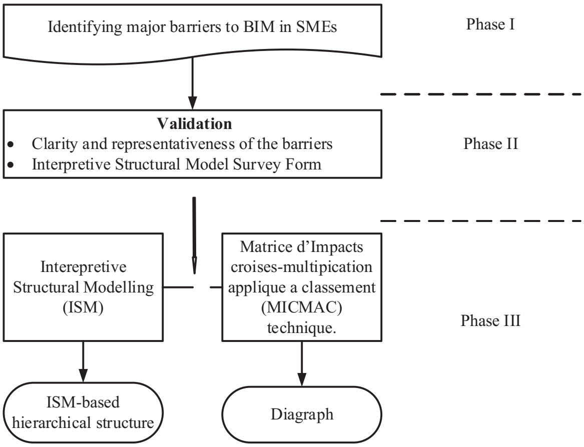

Figure 1. Research approach for the study

(2) *Phase II*: List of barriers affecting BIM in SMEs was compiled and presented to four experts with more than 10 years of experience during the pilot survey to validate the representativeness and clarity of the barriers. Suggestions given were considered and incorporated in the final survey form as shown in the Appendix.

(3) *Phase III*: Interpretive structural modelling (ISM) was adopted in this study as shown in Figure 2. The ISM was first proposed by Warfield (1974) for studying a complex system by decomposing it into multiple subsystems with experts knowledge and experience. The focus of the method is on the quality of the responses and not on the quantity of the respondents, thus, a few knowledgeable and experienced experts are often needed for the survey, which can be as few as two (Ravi and Shankar, 2005). This method is also beneficial when there are few experts in the area, this is applicable to this study as there are few experts on BIM in Nigeria's SMEs. Because of the efficiency of the technique, it has gained widespread adoption in the construction industry (Ahuja *et al.*, 2017; Chaple *et al.*, 2018; Mathiyazhagan *et al.*, 2013; Shen *et al.*, 2016) and other areas (Kumar and Purbey, 2018; Mor *et al.*, 2018; Talib *et al.*, 2011) for studying complex system. Thus, ISM is adopted in this study because of its strength to study complex system dynamics such as innovation adoption; its reliance on expert experience and quality of responses rather than the quantity. These make it the best fit for this study context where there are few experts and it would be difficult to have sufficient and valid responses through a survey approach.

The ISM steps are as follows:

- Establishing the hierarchical structure between the barriers.

This involves using ISM to establish the hierarchical structure between the identified barriers.

- Analysing the driving-power and dependence-power of barriers.

Duperrin and Godet (1973) developed the Matrice d'Impacts croises-multipication applique a classement (MICMAC) technique. It involves the classification of variables (barriers) into

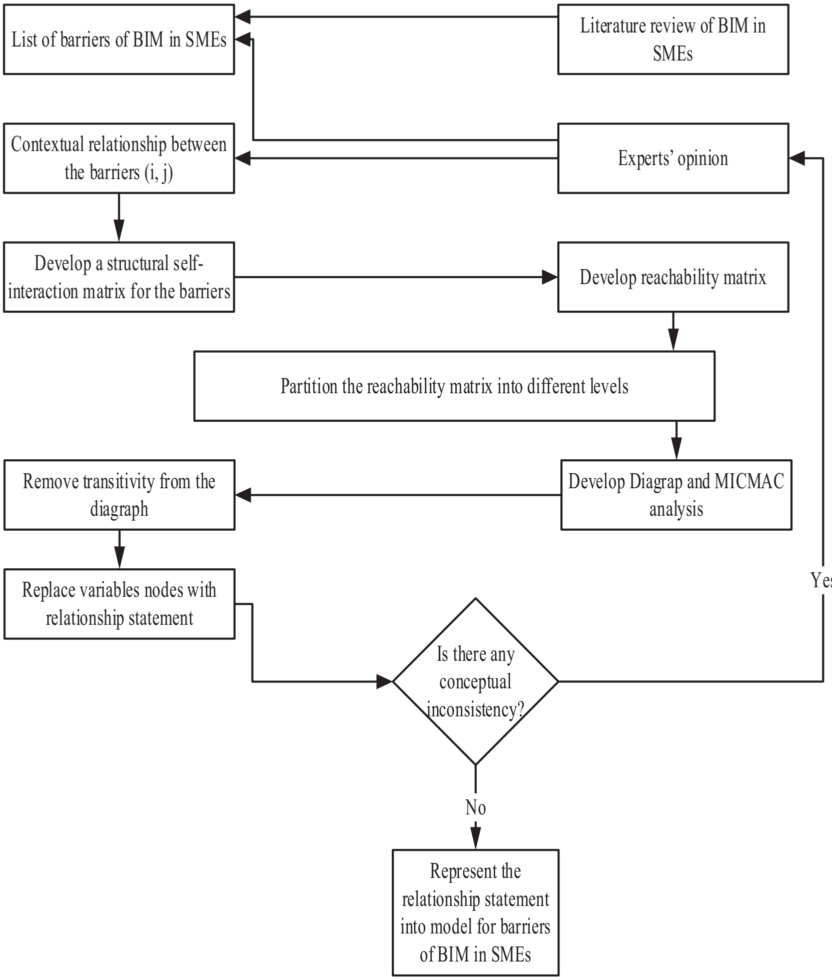

Figure 2.
ISM methodology

Source: Adapted from Mandal and Deshmukh (1994)

different categories based on the driving-power and dependence power. The driving-power is the horizontal sum (row-wise) of the relationship to and from a particular barrier "i" while the dependence power is the vertical sum (column-wise) of the relationship to and from a particular barrier "j". The technique makes the interactive relationship between the variables clearer and understandable. It presents the variables in the independent category, linkage category, autonomous category and dependent category.

Review of barriers to building information modelling in small and medium-sized enterprises
SMEs are influenced by both internal and external environment in which they operate. Table I shows the identified barriers, which were synthesised using three organisation theoretical lenses (TOE, IDT and INT) to cover for the various contexts.

Table I. Summary of literature review of barriers to BIM in SMEs

Contexts	Barriers	ID	Sources
a) Technology (TOE)	Complexity	B1	1
b) Compatibility, complexity and observability (IDT)	Interoperability of the BIM tools	B2	1, 2, 3 and 4
	Lack of tangible BIM benefits (observability)	B3	1, 2, 5 and 6
	Compatibility	B4	1, 2, 5, 7, 8, 6, 9 and 4
a) Environment (TOE)	Lack of government support/ institutional support	B5	3, 10 and 11
b) Mimetic pressure, coercive pressure and normative pressure (INT)	Lack of awareness by various stakeholders	B6	1, 2, 5, 12, 13, 8, 6, 14, 15 and 11
	Lack of client demand	B7	1, 2, 5, 6, 4, 14, 10 and 11
	Lack of implementation guide and strategies/standards	B8	2, 12, 13, 6, 4 and 10
a) Organisation (TOE)	Lack of support from top management	B9	1
	High cost of implementation	B10	16, 2, 5, 17, 7, 18, 12, 8, 6, 4, 14, 15, 11 and 20
	Resistance to change and strong will to retain the traditional method	B11	1, 2, 7, 18, 13, 8, 6, 4, 15 and 19
	Lack of financial resources	B12	2, 12, 13, 6 and 11
	High risk of implementation	B13	16, 2, 7, 18, 4, 11 and 21

Notes: 1 = Bosch-Sijtsema *et al.* (2017); 2 = Li *et al.* (2019); 3 = Joseph Garcia *et al.* (2018); 4 = Monozam *et al.* (2016); 5 = Hosseini *et al.* (2018); 6 = Hosseini *et al.* (2016b); 7 = Hong *et al.* (2018); 8 = Furry *et al.* (2017); 9 = Hosseini *et al.* (2016a); 10 = Poirier *et al.* (2015a); 11 = Bataw *et al.* (2014); 12 = Dainty *et al.* (2017); 13 = Caroll and McAuley (2017); 14 = Mellon and Kouider (2016); 15 = Anuar and Abidin (2015); 16 = Hong *et al.* (2019); 17 = Hochscheid and Halin (2018); 18 = Kouch *et al.* (2018); 19 = Olatunji (2011); 20 = Sebastian (2010); 21 = Charlson and Oduoza (2014)

Interpretive structural modelling-based analysis

Structural self-interaction matrix. A total of 25 BIM experts in the Nigerian construction industry were invited through emails for the ISM survey with phone calls as follow-up, however, only 16 experts completed the questionnaires. The experts were selected based on their experience and more than 80 per cent of them have at least 10 years of experience and they have participated in SMEs' projects either as contractors or consultants. A Web survey by sending emails with the fillable ISM form was used to reach experts that are far away, to facilitate anonymity and reliability of the responses (Olawumi and Chan, 2019a; Saka and Chan, 2019b). A major reason for the 64 per cent response rate could be partly explained by the technicality of the ISM survey form, which requires time and often requires an additional explanation from the researchers. This is considered sufficient as the focus is on the knowledge and experience of the experts rather than the quantity. Also, extant studies often have a lower number of respondents. Table II shows the demographic distribution of experts.

The experts were asked to determine the dynamic of the barriers (*i* and *j*) using four symbols (V, A, X and O), which denotes:

(1) V: Barrier *i* influences *j* and *j* does not influence *i*.

(2) A: Barrier *j* influences *i* and *i* does not influence *j*.

(3) X: Barrier *i* influences *j* and *j* also influences *i*.

(4) O: Barrier *i* and *j* have no links.

To avoid subjectivity in the aggregation of the responses, the principle "the minority gives way to the majority" was adopted as done in similar studies (Mathiyazhagan *et al.*, 2013; Mor *et al.*, 2018; Shen *et al.*, 2016). Table III shows the structural self-interaction matrix (SSIM) for the aggregated responses of the experts.

Initial reachability matrix. The SSIM is converted to an initial reachability matrix by using binary digits with the following rules:

Demographics	Category	No. (%)
Profession	Architect	6 (37.5%)
	Quantity surveyor	2 (12.5%)
	Engineer	3 (18.75%)
	Researcher	5 (31.25%)
Organisation	Contractor	4 (25%)
	Consultant	7 (43.75%)
	University/research institutes	5 (31.25%)
Years of professional experience	<5 years	–
	5-10 years	3 (18.75%)
	11-15 years	7 (43.75%)
	16-20 years	4 (25%)
	>20 years	2(12.5%)
Number of projects executed with BIM (either at the design stage or construction stage) as a consultant or contractor	1-3 projects	5 (31.25%)
	4-6 projects	8 (50%)
	7-9 projects	3 (18.75%)
	>10 projects	–

Table II. Demographic distribution of the experts

ID *Bi*	B13	B12	B11	B10	B9	B8	*Bj* B7	B6	B5	B4	B3	B2	B1
B1	O	O	V	O	V	O	O	O	O	O	O	A	X
B2	O	O	V	O	O	O	O	O	O	V	O	X	
B3	O	O	V	O	V	O	V	O	O	O	X		
B4	O	O	V	O	V	A	A	O	O	X			
B5	O	O	V	O	O	O	O	O	X				
B6	V	O	O	O	V	X	V	X					
B7	O	V	V	A	V	O	X						
B8	V	O	V	O	V	X							
B9	O	A	V	A	X								
B10	O	A	V	X									
B11	O	A	X										
B12	O	X											
B13	X												

Table III. SSIM for barriers to BIM in SMEs

- If the cell (i, j) is V, then cell (i, j) entry is 1 and cell (j, i) entry is 0.
- If the cell (i, j) is A, then cell (i, j) entry is 0 and cell (j, i) entry is 1.
- If the cell (i, j) is X, then cell (i, j) entry is 1 and cell (j, i) entry is 1.
- If the cell (i, j) is O, then cell (i, j) entry is 0 and cell (j, i) entry is 0.

The transformed initial reachability matrix is as shown in Table IV.

Final reachability matrix. The final reachability matrix is obtained from the initial matrix by incorporating the transitivity. This is a basic assumption in ISM and states that if barrier A is related to B and B is related to C, then A is necessarily related to C (Mandal and Deshmukh, 1994; Tan *et al.*, 2019). This could be executed by checking for each of the variable (barrier) manually or using loop statements. However, manual checking is error-prone and time-consuming. A Python function (shown below) was used (Xiang, 2013) to check the transitivity to ensure accuracy. Similar studies (Liu *et al.*, 2018; Shen *et al.*, 2016) often adopt MATLAB and this was crosschecked to validate the accuracy of the python function.

Barriers	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13
B1	1	0	0	0	0	0	0	0	0	0	1	0	0
B2	1	1	0	1	0	0	0	0	0	0	1	0	0
B3	0	0	1	0	0	0	1	0	1	0	1	0	0
B4	0	0	0	1	0	0	0	0	1	0	0	0	0
B5	0	0	0	0	1	0	0	0	0	0	1	0	0
B6	0	0	0	0	0	1	1	1	1	0	0	0	1
B7	0	0	0	1	0	0	1	0	1	0	1	1	0
B8	0	0	0	1	0	1	0	1	1	0	1	0	1
B9	0	0	0	0	0	0	0	0	1	0	1	0	0
B10	0	0	0	0	0	0	1	0	1	1	1	0	0
B11	0	0	0	0	0	0	0	0	0	0	1	0	0
B12	0	0	0	0	0	0	0	0	1	1	1	1	0
B13	0	0	0	0	0	0	0	0	0	0	0	0	1

Table IV. Initial reachability matrix for barriers to BIM in SMEs

```
def transitivity (matrix):
   result = ""
   length = len(matrix)
   for i in range(0, length):
      for row in range(0, length):
        for col in range(0, length):
          matrix [row] [col] = matrix [row] [col] or (matrix[row] [i]
          and matrix[i] [col])
      result += ("\n W" + str(i) +" is: \n" + str(matrix).replace
      ("],", "] \n") + "\n")
   result += ("\n Final Reachability Matrix is \n" + str(matrix).
   replace("],", "]\n"))
   print (result)
   return result
```

The transposed final reachability matrix when the function was called with the initial matrix using Python 3.4 is shown in Table V.

Hierarchical structure

The reachability set, antecedent set and intersection set were determined for each of the barriers to identify their partition level using the final reachability matrix. Reachability set for a barrier "i" consist of the barrier itself and other reachable barriers. Reachable barriers for a particular barrier are those with a value of 1 in its row on the final reachability matrix. Similarly, antecedent set for a barrier consists of the barrier itself and other reached barriers. Reached barriers for a barrier under consideration are barriers with the value of 1 in its column on the final reachability matrix. Intersection sets are the common barriers in both

ID	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	*Drp*
B1	1	0	0	0	0	0	0	0	0	0	1	0	0	2
B2	1	1	0	1	0	0	0	0	1*	0	1	0	0	5
B3	0	0	1	1*	0	0	1	0	1	1*	1	1*	0	7
B4	0	0	0	1	0	0	0	0	1	0	1*	0	0	3
B5	0	0	0	0	1	0	0	0	0	0	1	0	0	2
B6	0	0	0	1*	0	1	1	1	1	1*	1*	1*	1	9
B7	0	0	0	1	0	0	1	0	1	1*	1	1	0	6
B8	0	0	0	1	0	1	1*	1	1	1*	1	1*	1	9
B9	0	0	0	0	0	0	0	0	1	0	1	0	0	2
B10	0	0	0	1*	0	0	1	0	1	1	1	1*	0	6
B11	0	0	0	0	0	0	0	0	0	0	1	0	0	1
B12	0	0	0	1*	0	0	1*	0	1	1	1	1	0	6
B13	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Dpp	2	1	1	8	1	2	6	2	9	6	12	6	3	

Notes: *Transitive values; Dpp – dependence power; Drp – driving power

Table V.
Final reachability matrix for barriers to BIM in SMEs

the reachability and antecedent set for each of the barriers. Barriers with the same reachability set and intersection set are partitioned to level during each iteration of the reachability, antecedent and intersection set. From Table VI, B11 (resistance to change and strong will to retain the traditional method) and B13 (high risk of implementation) have the same reachability and intersection set. Following the ISM principle, these were partitioned to Level I and during the preceding iteration, the previous partitioned barriers were discarded.

B11 and B13 were cancelled out of the next iteration as they have been partitioned to Level I. B1 (complexity), B5 (lack of government support) and B9 (lack of support from top management) have their reachability set equal to intersection set, thus, they were partitioned to Level II as shown in Table VII.

Barriers	Reachability set	Antecedent set	Intersection set	Level
B1	B1 and B11	B1 and B2	B1	
B2	B1, B2, B4 and B11	B2	B2	
B3	B3, B4, B7, B9, B10, B11 and B12	B3	B3	
B4	B4, B9 and B11	B2, B3, B4, B6, B7, B8, B10 and B12	B4	
B5	B5 and B11	B5	B5	
B6	B4, B6, B7, B8, B9, B10, B11, B12 and B13	B6 and B8	B6 and B8	
B7	B4, B7, B9, B10, B11 and B12	B3, B6, B7, B8, B10 and B12	B7, B10 and B12	
B8	B4, B6, B7, B8, B9, B10, B11, B12 and B13	B6 and B8	B6 and B8	
B9	B9 and B11	B2, B3, B4, B6, B7, B8, B9, B10 and B12	B9	
B10	B4, B7, B9, B10, B11 and B12	B3, B6, B7, B8, B10 and B12	B7, B10 and B12	
B11	B11	B1, B2, B3, B4, B5, B6, B7, B8, B9, B10, B11 and B12	B11	I
B12	B4, B7, B9, B10, B11 and B12	B3, B6, B7, B8, B10 and B12	B7, B10 and B12	
B13	B13	B6, B8 and B13	B13	I

Table VI. Partition Level I

Barriers	Reachability set	Antecedent set	Intersection set	Level
B1	B1	B1 and B2	B1	II
B2	B1, B2 and B4	B2	B2	
B3	B3, B4, B7, B9, B10 and B12	B3	B3	
B4	B4 and B9	B2, B3, B4, B6, B7, B8, B10 and B12	B4	
B5	B5	B5	B5	II
B6	B4, B6, B7, B8, B9, B10 and B12	B6 and B8	B6 and B8	
B7	B4, B7, B9, B10 and B12	B3, B6, B7, B8, B10 and 1B2	B7, B10 and B12	
B8	B4, B6, B7, B8, B9, B10 and B12	B6 and B8	B6 and B8	
B9	B9	B2, B3, B4, B6, B7, B8, B9, B10 and B12	B9	II
B10	B4, B7, B9, B10 and B12	B3, B6, B7, B8, B10 and B12	B7, B10 and B12	
B12	B4, B7, B9, B10 and B12	B3, B6, B7, B8, B10 and B12	B7, B10 and B12	

Table VII. Partition Level II

Barriers that have been partitioned into the Levels I and II were removed from the iteration to arrive at reachability set, antecedent set and intersection set and only B4 (compatibility) have its reachability set as equal to its intersection set and it was partitioned to Level III as shown in Table VIII.

Similar steps were conducted to partition the remaining barriers. B2 (interoperability of the BIM tools), B7 (lack of client demand), B10 (high cost of implementation) and B12 (lack of financial resources) were partitioned to Level IV as shown in Table IX.

Similarly, B3 (lack of tangible benefits), B6 (lack of awareness) and B8 (lack of implementation guidelines and standards for SME) were partitioned to Level V as shown in Table X.

The identified levels of the barriers from Tables VI-X were used to obtain the ISM-based hierarchical structure of the 13 identified barriers as shown in Figure 3.

Matrice d'Impacts croises-multipication applique a classement analysis

The MICMAC is used to categorise the barriers into autonomous, dependent, linkage and independent categories depending on their dependence power and driving power (Table V). The highest value in the dependence power and driving power is a value of 12 on the *x*-axis,

Barriers	Reachability set	Antecedent set	Intersection set	Level
B2	B2 and B4	B2	B2	
B3	B3, B4, B7, B10 and B12	B3	B3	
B4	B4	B2, B3, B4, B6, B7, B8, B10 and B12	B4	III
B6	B4, B6, B7, B8, B10 and B12	B6 and B8	B6 and B8	
B7	B4, B7, B10 and B12	B3, B6, B7, B8, B10 and B12	B7, B10 and B12	
B8	B4, B6, B7, B8, B10 and B12	B6 and B8	B6 and B8	
B10	B4, B7, B10 and B12	B3, B6, B7, B8, B10 and B12	B7, B10 and B12	
B12	B4, B7, B10 and B12	B3, B6, B7, B8, B10 and B12	B7, B10 and B12	

Table VIII.
Partition Level III

Barriers	Reachability set	Antecedent set	Intersection set	Level
B2	B2	B2	B2	IV
B3	B3, B7, B10 and B12	B3	B3	
B6	B6, B7, B8, B10 and B12	B6 and B8	B6 and B8	
B7	B7, B10 and B12	B3, B6, B7, B8, B10 and B12	B7, B10 and B12	IV
B8	B6, B7, B8, B10 and B12	B6 and B8	B6 and B8	
B10	B7, B10 and B12	B3, B6, B7, B8, B10 and B12	B7, B10 and B12	IV
B12	B7, B10 and B12	B3, B6, B7, B8, B10 and B12	B7, B10 and B12	IV

Table IX.
Partition Level IV

Barriers	Reachability set	Antecedent set	Intersection set	Level
B3	B3	B3	B3	V
B6	B6 and B8	B6 and B8	B6 and B8	V
B8	B6 and B8	B6 and B8	B6 and B8	V

Table X.
Partition Level V

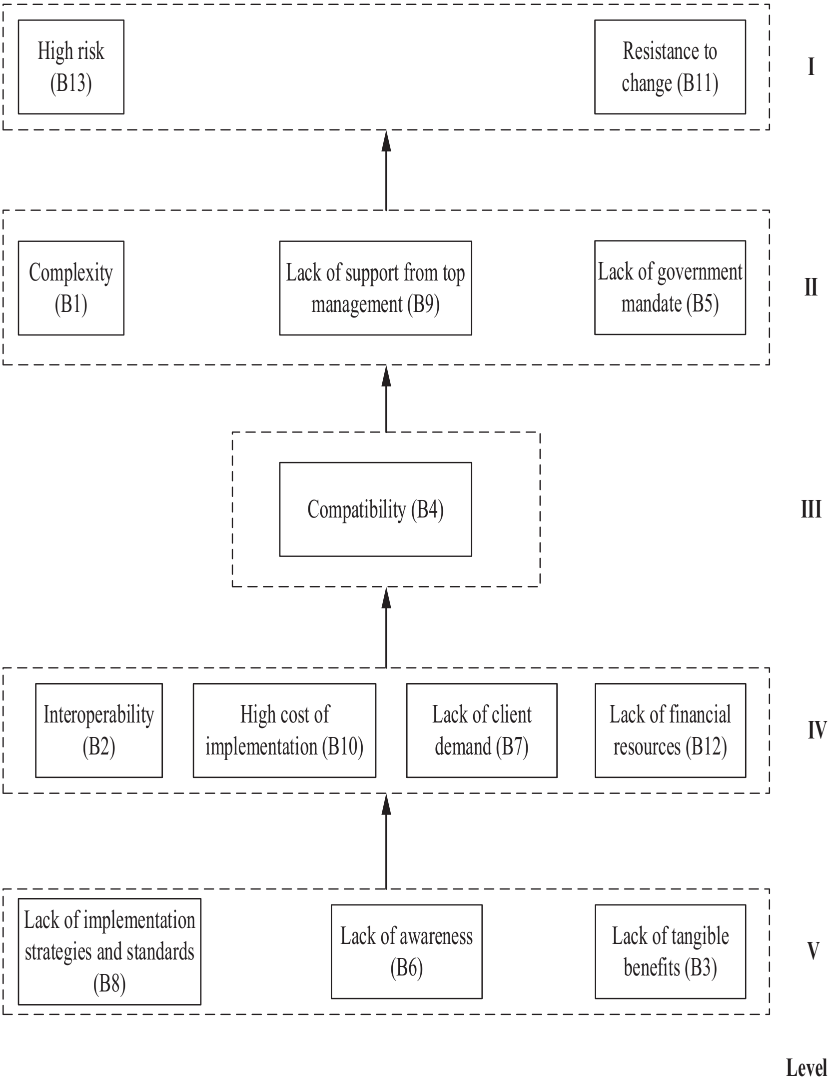

Figure 3.
ISM for BIM barriers from SMEs

and the minimum is 1, therefore, the axis ranges from 1 to 12 (11 units) and the half is 5.5. This is used to partition the barriers in a two-dimensional diagram (diagraph) as shown in Figure 4.

- *Autonomous category*: These are barriers with weak driving power and weak dependence power. They are disconnected from the main system and have few links. These barriers are "complexity", "interoperability of the BIM tools", "lack of government support" and "high risk of implementation";
- *Dependent category*: These are barriers with weak driving power but strong dependence power. They are dependent on other barriers and can be addressed by

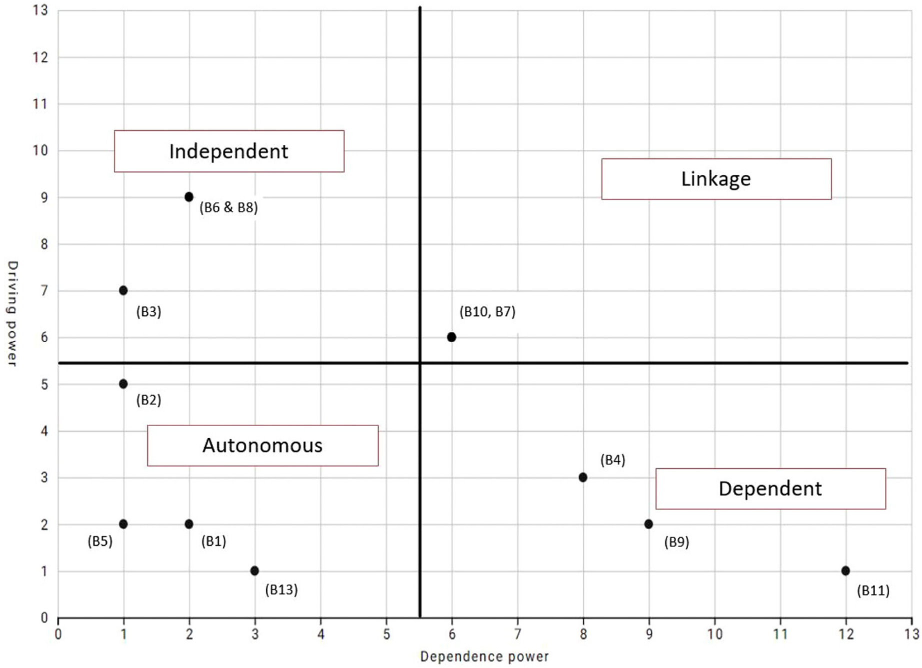

Figure 4. Diagraph and MICMAC analysis of the barriers to BIM in SMEs

Notes: B1: Complexity; B2: Interoperability of the BIM tools; B3: Lack of tangible BIM benefits (Observability); B4: Compatibility; B5: Lack of government support/institutional support; B6: Lack of awareness by various stakeholders; B7: Lack of client demand; B8: Lack of implementation guide and strategies/standards; B9: Lack of support from top management; B10: High cost of implementation; B11: Resistance to change and strong will to retain the traditional method; B12: Lack of financial resources; B13: High risk of implementation

addressing-related barriers. They represent unfavourable results. These barriers are “compatibility”, “lack of support from top management” and “resistance to change and strong will to retain traditional method”;

- *Independent category*: These are barriers with strong driving power but weak dependence power. These are considered as the most important barriers. They are “lack of tangible benefits”, “lack of awareness” and “lack of implementation guidelines and strategies/standards”; and
- *Linkage category*: These are barriers with both strong driving power and dependence power. These barriers affect other barriers and have feedback on themselves. They are “lack of client demand” and “high cost of implementation”.

Discussion of findings

Sustainable adoption and implementation of BIM is a big challenge for SMEs because of challenges such as lack of financial resources, high cost of implementation and so on. The problem is complicated for SMEs in developing countries such as Nigeria with a low level of awareness and adoption of BIM. Thus, this present study aimed to study the dynamics of these barriers by drawing from IDT, INT and TOE framework. Barriers were reviewed, refined and grouped into technology context, external environment and organisation (internal environment) context to study the problem from a sociotechnical perspective. The ISM approach shows that the barriers are related to each other and would affect the adoption of BIM in SMEs in different ways.

The barriers were partitioned into five levels using the ISM principle. Level I posit an interesting finding as this level is the most critical and the barriers, which include resistance to change and strong will to retain traditional method and high risk of implementation is from the organisation context. It contradicts the conclusion of Bataw *et al.* (2014) in the UK construction industry that lack of government support is the biggest barrier for SMEs. However, the finding reinforces the fact that organisation should be of utmost importance in driving BIM implementation in SMEs and resonates with Bosch-Sijtsema *et al.* (2017) in the Swedish construction industry and Oladapo (2007) in the Nigerian construction industry. It corroborates Sexton *et al.* (2006) that companies should be of major focus and not projects for small firms. The resistance to change and the perception that BIM is risky is the major hindrances of BIM in SMEs in Nigeria and resonates with the findings of Saka *et al.* (2019d) and Hong *et al.* (2018). SMEs are resistant to change as they perceived BIM to be far away from their comfort zone, which makes it risky. The implementation also consists of many contractual and legal uncertainties such as ownership, data reliance, risk-sharing and standard of care. This could also be responsible for the strong will to retain the traditional approach, which they are familiar with the procedures.

Level II consists of the complexity of BIM tools, lack of government support and lack of support from the top management, which is from technology context, external environment and organisation context, respectively. This depicted the sociotechnical perspective of the BIM adoption in SMEs. The complexity of the BIM tools would also lead to resistance to change and strengthen the perception of the SMEs as regards the risk attached to BIM. Lack of top management support and lack of government support are also important barriers influencing the adoption of BIM. This captures the lack of government mandate as regards BIM in the Nigerian construction industry and in other similar developing economies. Government mandate may prompt the SMEs to adopt BIM, however, this may not be too influential for SMEs that are not working on government projects (Lam *et al.*, 2017). A large percentage of SMEs in Nigeria often work on government projects either as the main contractor on small to medium-sized public projects or as subcontractors on large public projects. It is worthwhile to note that without the government mandate, which is secondary as reflected in the ISM model, the SMEs can still adopt and benefits from BIM by an internal drive, which is in tandem with Poirier *et al.* (2015a).

Lack of compatibility of BIM with the job at hand is partitioned to Level III and this could lead to barriers in Level II. Most SMEs are of the perception that BIM is meant for large projects (Hosseini *et al.*, 2016a) and is not applicable to their small to medium-sized projects, which will lead to a lack of support and adversely lead to resistance to adopting BIM by the stakeholders. A change in this perception is needed to drive a paradigm shift in the SMEs, and would consequently lead to BIM adoption, which extant studies (Hong *et al.*, 2016; Poirier *et al.*, 2015b) have revealed to be compatible and beneficial for the SMEs.

Similarly, a critical look at Levels III and IV reveal that the partitioning draws from the technology context, external environment and organisation context. This further reinforces that the BIM innovation process in SMEs is influenced by both internal and external forces within the environment, which it operates. SMEs cannot operate independently on their own without coming into contact with its environment. Lack of client demand, lack of financial resources, interoperability of the BIM tools and high cost of implementation are partitioned on Level IV of the model while lack of tangible BIM benefits, lack of awareness of the stakeholders and lack of implementation guides/standard for SMEs are partitioned on Level V. It revealed that despite these challenges, individual SME can still adopt and implement BIM successfully in their organisation, which is the current practice in Nigeria (Kori *et al.*, 2019).

MICMAC analysis and the digraph categorised the barriers into autonomous, dependent, linkages and independent barriers. The linkage barriers, which are the high cost of implementation and lack of client demand are sensitive and often affect other barriers. The high cost of implementation, which consists of both the cost of BIM tools and training would affect the feasibility of adopting BIM for SMEs with a lack of access to adequate financial resources. Similarly, lack of client demand would influence other barriers as it may lead to a lack of adequate financial resources and a lack of support from top management. Client demand and high cost of BIM implementation are thus sensitive and would influence other barriers. The dependent barriers, on the other hand, are compatibility and lack of support from top management. These barriers can be solved by addressing other similar barriers, for instance, client demand for BIM on their projects would lead to support of top management and would also lead to usage of BIM on the projects (compatibility). Also, the government mandate would lead to support by SMEs' top management on public projects where they are the main contractor or subcontractor. Similarly, lack of tangible BIM benefits, lack of awareness of the stakeholders and lack of implementation guidelines are considered to be independent and very important for the proliferation of BIM in SMEs. This supports the findings that there is still a lack of awareness of BIM in SMEs in Nigeria (Kori *et al.*, 2019), lack of implementation strategy (Ghaffarianhoseini *et al.*, 2016a) and lack of tangible BIM benefits (Saka *et al.*, 2019e). There is a need for an increase in awareness of BIM in Nigeria, which would lead to increase in adoption of BIM, also there is need to provide implementation strategies for SMEs in Nigeria and the need to make local BIM projects' reports available, which would emphasise the immense benefits attached to the adoption of BIM.

Conclusions

Although there are many extant studies on BIM barriers in the construction industry, the main thrust of this study is its focus on the SMEs in a BIM infant country like Nigeria. The study set out the dynamics of BIM barriers from the perspective of SMEs in developing countries, which little attention has been paid to in extant studies. It revealed the major barriers hindering BIM adoption in SMEs and their interrelationships with each other. The findings underscore that the SMEs can adopt BIM by internal will and drive from within the organisation. Also, it revealed that the adoption process is a complex sociotechnical system one with forces from the external environment, internal environment and technology context. It provides the dynamics of identified barriers and revealed the autonomous barriers, dependent barriers, linkage barriers and independent barriers. These findings have important theoretical and practical implications. Firstly, the study contributes to the few studies on BIM in SMEs especially from developing countries and is built on grounded seminal works. Secondly, the ISM method overcomes the limitations of existing methods in extant studies on BIM in developing countries by focussing on the experts and decomposing the system into subsystems. This presents the barriers in a different hierarchical model compared to mean score ranking in extant studies. Thirdly, it presents the dynamics of the barriers and categorise the barriers for easy intervention by the policymakers and stakeholders. Finally, the study revealed that despite the lack of clear government support for BIM in BIM infant countries, SMEs can still initiate the adoption of BIM by focussing on their organisations' context.

Albeit few experts responded to the questionnaire survey, which may serve as a limitation of the study; however, the focus of the ISM is on the quality of the responses rather than the quantity of responses. Thus, the experts selected were deemed knowledgeable and with sufficient BIM experience. Also, only 13 barriers were adopted in this study against the larger number of challenges in extant studies, however, the 13 barriers were carefully reviewed, refined and selected and serve as major barriers in the extant studies. These major barriers can be deconstructed into subchallenges. The study considered Nigeria as a case study of developing countries in this study, the findings can be extrapolated to other BIM infant developing countries with a low level of BIM adoption. Finally, as this is a nascent area of research in developing countries with BIM infant industries, the results are exploratory and not statistically validated. A further area of research would be to integrate other analytical methods to validate the proposed hierarchy model proposed in this study.

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Further reading

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Appendix

This questionnaire survey aims to draw on the abundant knowledge and hands-on experience in the construction industry and BIM of both academic researchers and industrial practitioners to help evaluate the relationship amongst the identified major drivers and challenges of adopting BIM in SMEs of developing countries with the Nigerian construction industry as a case study.

SECTION A: Expert's Background Information

1. Please indicate your key profession in the construction industry:

   a) Architect b) Quantity Surveyor c) Engineer d) Builder

   e) Project Manager f) Academic/Research

   g) Other (*please specify*):

2. Type of organisation in which you are currently engaged:

   a) Contractor b) Consultant c) Subcontractor d) Designer

   e) Client f) University/Research Institute

   g) Other (*please specify*):

3. Years of professional experience in the construction industry:

   a) < 5 years b) 5 – 10 years c) 11 – 15 years d) 16 – 20 years

   (e) > 20 years

4. Number of Projects executed with BIM (Either at the design stage and or construction stage) as a consultant or contractor a) 0 project b) 1 – 3 projects c) 4 – 6 projects

   d) 7 – 9 projects (e) 10 or more projects

SECTION B: Major Barriers of Building Information Modelling (BIM) Adoption in the Nigerian Construction Small and Medium-Sized Enterprises (SMEs)

Please fill in the white boxes of the following table using one of the following symbols:

V= barrier Bi will help to achieve/alleviate barrier Bj

A= barrier Bj will help to achieve/alleviate barrier Bi

X= barriers Bi and Bj will help to achieve/alleviate each other

O = barriers Bi and Bj are unrelated

ID	Barriers	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1
B1	Complexity													
B2	Interoperability of the BIM tools													
B3	Lack of Clear BIM benefits (Observability)													
B4	Compatibility													
B5	Lack of government support/ institutional support													
B6	Lack of awareness by various stakeholders													
B7	Lack of client demand													
B8	Lack of implementation guide and strategies/standards													
B9	Lack of management support													
B10	High cost of implementation													
B11	Resistance to change													
B12	Lack of financial resources													
B13	High risk of implementation													

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