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Barriers to BIM implementation and ways forward to improve its adoption in the Nigerian AEC firms

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Barriers to BIM implementation and ways forward to improve its adoption in the Nigerian AEC firms

Abstract

Purpose –BIM has much potential to improve the effectiveness of construction works with respect to design, construction and maintenance. However, many Architecture, Engineering, and Construction (AEC) firms are still lagging in the adoption and implementation of BIM in both developing and developed countries. The purpose of this study is to assess the barriers to BIM implementation, and examine the ways forward to improve BIM adoption within the Nigerian AEC firms.

Design/methodology/approach – A comprehensive literature review and questionnaire survey were used in the study. The survey targeted four different AEC firms. These include architectural firms, facility management firms, quantity surveying firms and structural engineering firms in Lagos, Nigeria. The data obtained were analyzed using mean score, standard deviation, Kruskal-Wallis test, and factor analysis.

Findings – The study identified 20 barriers to BIM implementation and identified 10 ways forward to improve BIM adoption in AEC firms, particularly in Nigeria. The relative importance of both the identified barriers and the ways forward were gauged. The Kruskal-Wallis tests revealed that except for one (out of 20) identified barriers, and one (out of 10) identified ways forward; there is no statistical significant difference in the perceptions of four different AEC firms. The factor analysis result grouped the 20 identified barriers into three major factors to include: weak top management support and BIM environment related issues; cost of BIM software and training issues; and incompatibility, legal, contractual, and culture related issues.

Practical implications – The significance of the study cannot be over-emphasized due to BIM relevance to construction stakeholders and researchers at large.

Originality/value – The study findings would inform the decisions of the construction stakeholders to make some policy recommendations capable of positively influencing the full BIM implementation in AEC firms.

Keywords AEC firms, BIM, barriers, construction stakeholders, construction industry, developing countries

Paper type Research paper

Introduction

The construction industry had been plagued by various problems such as fragmented project delivery processes that are based on paper-oriented means of communication, which was prone to human errors, and omissions that usually lead to cost overrun, prolong delays, and disputes among the stakeholders in construction projects (Eastman *et al.*, 2008). However, the AEC firms in a bid to mitigate these challenges developed many methods such as design and build method, project web sites and 3D CAD tools (Eastman *et al.*, 2008). Although these methods enhance the rapid exchange of information, it has not been able to eradicate the problems associated with

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3 paper-oriented means of communication such as inability to detect parametric capability,
4 conflicts and constructability issues among others (Abdullah and Ibrahim, 2016). Building
5 information Modeling (BIM) was developed to provide basis for resolving the inefficiencies of
6 the previous Computer Aided Drawing (CAD) by providing a working digital environment that
7 incorporates all information about a building in an electronic file, and used by the various project
8 stakeholders (Abdullah and Ibrahim, 2016). Aouad *et al.* (2014) described BIM as a virtual
9 demonstration of functional features of a project. BIM is one of such inventive methods that have
10 the potential to bring about the incessant progress and anticipated changes in the construction
11 industry and reform the methods of its operation to accomplish enhanced cooperation among
12 contractual parties and ascertain successful delivery of project (Azhar, 2011). BIM is currently
13 regarded as a fast growing digital technology having the inherent attributes to improve the
14 management of information in construction (Migilinskas *et al.*, 2013). However, Alufohai (2012)
15 argued that BIM adoption has not been generally embraced by AEC firms in both developed and
16 developing countries and has experienced stunt growth due to challenges associated with BIM
17 usage. This statement has been corroborated by Eadie *et al.* (2013) who asserted that there are
18 various factors hindering the progress of BIM.
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23 In Nigeria, the construction industry is more fragmentized that various construction professionals
24 usually generate project information and manage them individually (Onungwa *et al.*, 2017).
25 Hamma-adama *et al.* (2017) and Kori (2015) claimed that architectural, mechanical, electrical
26 and plumbing designs are still prepared using 2D CAD platform with only few (especially
27 Architects) using 3D CAD platform basically for visualization or demonstration. This is affirmed
28 by Hamma-adama *et al.* (2017) that the current status of BIM uptake in Nigeria is the
29 predominant usage of 2D and 3D. Smith and Tardif (2009) argued that if BIM is used merely for
30 presentation, detection of clashes and visualization, the numerous inherent capabilities it
31 possesses may remain un-tapped. It can be deduced that these restricted uses of BIM reflect
32 deficiency of BIM knowledge within the Nigerian construction industry context (Ugochukwu *et*
33 *al.*, 2015). Also, Ibrahim and Bishir (2012) asserted that BIM adoptions and usage in most
34 developed nations are on the increase, however, the extent of BIM adoption particularly in
35 developing countries is best describe as stagnant.
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39 Relevant previous BIM studies in Nigeria were specific to a particular firm. For example, studies
40 on BIM adoption and awareness in architectural firms (see Ibem *et al.*, 2018; Kori and Makarf,
41 2018; Kori *et al.*, 2019). BIM studies in facility management firms (see Ikediashi and Joseph,
42 2016; Olapade and Ekemode, 2018) among others. In addition, studies that examined BIM
43 adoption, awareness, and implementation among Architecture, Engineering, and Construction
44 (AEC) firms (see Olugboyega and Aina, 2016; Onungwa *et al.*, 2017; Ganiyu *et al.*, 2018;
45 Olabode and Umeh, 2018). Few studies assessed BIM training gaps among construction
46 professionals (see Oyewole and Dada, 2018). Few other studies examined BIM maturity level
47 among AEC firms comprised architectural firms, facility management firms, quantity surveying
48 firms, and structural engineering firms (see Babatunde *et al.*, 2019). It is evident from the
49 aforementioned previous studies that they are not only specific to a particular firm, but they also
50 focused on BIM awareness and utilization in Nigeria. It is therefore expedient to carry out an
51 explicit study that comprises a comparative analysis with particular emphasis on barriers to BIM
52 implementation in each AEC firm with a view to having a balanced knowledge of BIM
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3 implementation among AEC firms in Nigeria. The quest to fill this knowledge gap is what
4 birthed the need for this study. It is believed this study would provide a better insight of Nigeria
5 BIM environment that is a true reflection of developing countries at large. This study would
6 further inform the decisions of the construction stakeholders to make some policy
7 recommendations capable of positively influencing the full BIM implementation in AEC firms.
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11 12 **Literature review**

13 *Current state of BIM implementation in the Nigerian construction industry*

14 Onungwa *et al.* (2017) asserted that there is low level of awareness and technical know-how of
15 BIM in Nigeria. This can be linked to lack of adequate BIM training and inadequate exposure to
16 BIM concept (Abubakar *et al.*, 2013; Onungwa *et al.*, 2017). In Nigeria, both medium and large-
17 sized firms involved in construction activities are predominantly at the forefront in the
18 implementation of BIM (Kori, 2015). However, firms that are relatively small in size rarely use
19 BIM in their practices. Generally, the construction industry in Nigeria is fragmented, this
20 implies that various construction professionals usually generate project information and manage
21 them individually. Hamma-adama *et al.* (2017a) and Kori (2015) found that architectural,
22 mechanical, electrical and plumbing designs are still prepared using 2D CAD platform with only
23 few, especially architects using 3D CAD platform basically for visualization or demonstration.
24 Smith and Tardif (2009) argued that if BIM is used merely for presentation, detection of clashes
25 and visualization, the numerous inherent capabilities it possesses may remain un-tapped.
26 Similarly, these restricted uses of BIM reflect deficiency of BIM knowledge in the Nigerian
27 construction industry (Ugochukwu *et al.*, 2015). Hamma-adama *et al.* (2017b) opined that change
28 of behavior from the traditional method of procurement is necessary, but change of behavior to
29 successfully implement BIM is often difficult as it requires a complete transition of work
30 processes.
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35 Although BIM implementation in most developed nations are on the increase, however, the
36 extent of BIM implementation in most developing nations such as Nigeria is best described as
37 stagnant (Ibrahim and Bishir, 2012). This is affirmed by Hamma-adama *et al.* (2017a) that the
38 current status of BIM uptake in Nigeria is the predominant usage of 2D and 3D. However, a
39 more comprehensive and exhaustive examination of the levels of development of BIM in the
40 Nigerian construction industry by Olugboyega and Aina (2018) showed that both two
41 dimensional and various variants of three dimensional building information modeling such as 3D
42 architectural model, 3D architectural and structural model and 3D architectural and building
43 services model were the most widely used in Nigeria. It is quite unfortunate there are no
44 government policies in place to encourage BIM implementation in Nigeria, which is a true
45 reflection of developing countries as whole. Studies have shown that currently BIM
46 implementation in Nigeria is been requested mostly by private building owners and corporate
47 organizations while the governments at all levels (i.e. federal, state and local) are not showing
48 much interest in the implementation of BIM for the delivery of public projects.
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53 *Comparative review of BIM adoption: global context*

54 The usage of BIM has transformed the construction industry. Increase in profit via cost savings
55 and timely delivery of projects are some of the numerous advantages of using BIM for
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3 construction works. United Kingdom BIM Strategy Report (2012); Wong *et al.*(2009) and
4 BuildSmart (2012) reported that several governments of developed countries including the
5 United Kingdom, United States of America, Australia among others have set up strategies for the
6 implementation of BIM in their construction works which has led to rapid BIM adoption. For
7 instance, Efficiency and Reform Group (2011) established a road map for the adoption of BIM in
8 the United Kingdom to implement BIM and achieve efficacies. In Australia, government had
9 proposed compulsory usage of BIM on public financed projects as from the first phase of year
10 2016 (BuildSmart, 2012). A survey conducted by Kjartansdottir (2011) on the adoption of BIM
11 in Iceland showed that not less than forty percent of construction professionals use BIM in their
12 practices, especially architects and engineers.
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16 BIPS (2012) reported that Denmark and Norway are among the countries that have developed
17 proficiency in the implementation of BIM, having mandated the usage of BIM on public projects
18 since 2007. The adoption of BIM in the United States of America showed a significant increase
19 in BIM usage from twenty-eight to forty-eight percent which is far more than the percent in other
20 developed countries (McGraw-Hill, 2009; Eadie *et al.*, 2014). McGraw-Hill (2008) found out
21 that sixty-two percent of the respondents showed willingness to use BIM on not less than thirty
22 percent of their project in 2009; eighty-two percent of BIM users admit increase in output of
23 work done and forty-four percent are currently using BIM to ascertain “Return On Investment”.
24 According to McGraw-Hill (2009) most BIM users obtained numerous advantages from using it
25 and the percent of BIM usage to find out return on investment has risen to sixty-three percent.
26 The implementation of BIM is fast-growing as building owners and government agencies were
27 prompted to adopt BIM, based on its benefits such as timeliness, reasonability of project cost and
28 high quality among others. It is therefore evident that most nations of the world recognized the
29 inherent capability of such innovative processes for reformation of practices in the construction
30 industry. Lee *et al.* (2014) stated that BIM processes were made compulsory by the United States
31 of America and United Kingdom government agencies to assist construction professionals’
32 practices in the industry and to satisfy and surpass clients’ needs and expectations; they further
33 stated that since 2006, the United States of America general services administration incorporated
34 programme such as spatial arrangement of BIM as one of the least prerequisite for final approval
35 of proposals.
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40 As a result, the United States of America has been recognized as a leading country in the BIM
41 implementation, subsequently the adoption level in North America sky-rocked from twenty-eight
42 percent to seventy-one percent within the period of 2007 and 2012, and similar experiences were
43 reported in the United Kingdom with contractors and architects adoption level amounting to
44 seventy-four and seventy percent respectively (McGraw-Hill, 2014). According to Matarneh and
45 Hamed (2017), the government of the United Kingdom has a foresight of becoming the frontier
46 of BIM in Europe; they further stated that despite the increase in the usage of BIM world-wide,
47 the experience in relation to BIM differs from one construction to another. Singh (2017)
48 investigated BIM adoption in developed nations and found that in Finland, BIM implementation
49 commenced since in 2002 and by 2007, it was established that all design must be IFC certified.
50 In Norway, BIM and IFC data format had been used since 2010; In Denmark, government had
51 mandated the usage of BIM coupled with research and development works in relation to BIM are
52 currently conducted at the organizational and institutional level; In Sweden, BIM is widely
53 adopted without compulsion from the government but are only deficient in BIM research
54 publications when compared to the United States of America; In Singapore, government
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3 encouraged the implementation of BIM by making the usage of BIM mandatory for large project
4 and provision of adequate fund for the training and procurement of BIM software and hardware;
5 In France, the government officials in a bid to fully adopt BIM, resolved in 2014 to use BIM in
6 the development of not less than five hundred houses by 2017; South Korea being one of the
7 frontiers of BIM adopters had been making tremendous efforts since 2010 to cause an increment
8 in the number of BIM oriented projects by the provision of funds for the establishment of BIM-
9 oriented building design standards and mandatory use of BIM on all government projects over
10 fifty million dollars since 2016.
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13 China Construction Industry (2013) reported that BIM adoption level in China is very low; this is
14 however attributed to government not acting as “role model” in the adoption of BIM. In Hong
15 Kong, Lu *et al.* (2018) found that BIM maturities of construction-related organizations in Hong
16 Kong vary, with more than half ranging from Stage 0 to 1; and this was attributed to the different
17 developments of their BIM processes and protocols. However, the BIM implementation in Africa
18 differs from one country to another. For instance, in South Africa construction professionals are
19 still confronted with barriers in the adoption of BIM (Succar, 2009). In Nigeria, the BIM
20 awareness is relatively high compared to its usage among AEC firms (Ogwueleka, 2015). This is
21 corroborated by Ugochukwu *et al.* (2015) that not less than sixty-seven percent of construction
22 professionals are aware of BIM in Nigeria but very few have implemented BIM in their
23 practices. It is surprising that BIM has been rarely used for construction works in Nigeria
24 (Alufohai, 2012). This is affirmed by Olugbenga *et al.* (2016) that currently BIM usage in
25 Nigeria is been requested mostly by building owners and developers but the government is not
26 showing any interest in the implementation of BIM for the delivery of public projects. Against
27 this backdrop, this study becomes necessary to critically examine the militating factors to BIM
28 full implementation and the ways forward to improving its adoption among AEC firms in
29 Nigeria.
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36 *Barriers to BIM implementation among AEC firms*

37 BIM implementations have not been generally embraced by many AEC firms, particularly in
38 developing countries. Thus, some selected barriers to BIM implementation as identified by
39 previous studies are briefly discussed as follows:
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41 *The structure of the construction industry*

42 BIM implementation usually involves a complete change in practice with respect to procedures
43 and principles (Ezeokoli *et al.*, 2016). Kori and Arto (2015) opined that the attitude of
44 construction professionals to change from an existing process to a new one poses more problems
45 than acquiring the skills. This is because traditional method of procurement has been used long
46 enough that it is extremely difficult to embrace a new process. Zahrizan *et al.* (2013) argued that
47 managers at the corporate level had been identified as a key factor that brings about incessant
48 incorporation of changes to innovation. However, when these managers are duly informed,
49 incorporating changes in the firms become easy, thus for any firm to change from the
50 conventional means of procurement requires taking deliberate steps to embrace the
51 implementation of BIM.
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Low level of BIM technical know-how and awareness

Zahrizan *et al* (2013) argued that the obscurity of BIM in the construction industry can be traced to the relatively inadequate level of awareness and technical know-how of BIM among construction professionals. Liu *et al.* (2015) recognized inadequacy of appropriate skills and technical know-how in the usage of BIM as one of the major barriers to the adoption of BIM in their individual nations. Saxon (2013) noted that currently BIM is often utilized and is experiencing instantaneous growth in most developed nations. For example, RICS (2014) reported that BIM was applied on more than seventy percent and thirty-six percent of the construction works in the United States of America and Europe respectively, but this is in contrast to what is prevalent in Africa. Although the awareness level is increasing progressively, the degree to which BIM is been implemented on construction works is seemingly low. For instance, Hosseini *et al.* (2015) found out that about twenty-nine percent of the construction firms in Iran adopted BIM in their practices and about fifty-six percent have not heard of BIM. Saxon (2013) claimed that only fewer number of BIM applications are recorded in developing countries because construction participants are yet to develop capability to use BIM.

Inaccessibility to suitable technology and framework

Accessibility to BIM technology and framework had a significant effect on BIM implementation. For instance, Zahrizan *et al* (2013) asserted that even if firms embrace changes from an existing process to a new one without accessibility to suitable technology such changes will be short leave. They further identified that the inability to gain access to technology and framework serve as a major barrier to the implementation of BIM in most developing nations. Obiegbo and Ezeokoli (2014) argued that BIM technologies available for sale are costly to procure and set-up. Thus, new BIM users might incur excessive expenses which might even affect their profit at the early stage (Hergunsel, 2011).

Individual perception/ point of view

Zahrizan *et al* (2013) claimed that most construction professionals in developing nations are somewhat afraid of the implementation of BIM in their practices. Simply because it requires a transition from the conventional processes prevalent in the construction industry, thus reluctance to embrace improved but new working environment becomes one of the foremost barriers impending the usage of BIM.

Absence of appropriate BIM guidelines

It is a mere illusion to desire the attainment of purposeful changes without procedure and regulation in place to implement it (Ezeokoli *et al.*, 2016). Inadequate support from the government for BIM implementation and general regulation has been recognized to have a negative impact on the usage of BIM, thus each BIM user adopt their own principle without directive from the vendor which will inevitably result to differences in the detail level in relation to various firm (Zahrizan *et al.*, 2013; Abubakar *et al.*, 2014).

Industry/working environment

With the varieties of software packages at the disposal of designers (Architects and engineers) to generate designs that are better than the conventional or traditional practice, it is evident that the incorporation of data in the electronic model of buildings has successfully eradicated many possible disputes but has not been able to incorporate the rudiment of business procedure. In the absence of such procedures, data and associated tools will not develop appropriately due to its inability to indicate progress of work being done and collaboration of data (Bernstein and

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3 should be made compulsory for all procurement processes and contracts and finally, setting up
4 BIM council. Alufohai (2012) suggested that software vendors and relevant training institutes
5 should embark on intensive awareness of BIM, BIM tools and associated benefits. The author
6 further proffered that the relevant professional bodies both local and international should keep
7 their member up-to-date by organizing trainings, workshops, and seminars on BIM
8 implementation. Isa (2015) identified strategies for overcoming BIM barriers to include improve
9 BIM awareness and understanding, outsourcing BIM experts, provision of training by employers,
10 provision of BIM education at higher institutions, government legislation supporting the use of
11 BIM, clients demand for BIM, government support, developing BIM guidelines and improved
12 data exchange standards. It is obvious that several measures to improve BIM implementation
13 have been identified, but none of these measures have been investigated, particularly through an
14 empirical approach in Nigeria. Therefore, it becomes imperative to empirically assess the
15 measures to improve the implementation of BIM among AEC firms in Nigeria. It is against this
16 backdrop that four different AEC firms were considered in this study. These include architectural
17 firms, facility management firms, quantity surveying firms and structural engineering firms in
18 Lagos, Nigeria.
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24 **Research methodology**

25 The study utilized literature review and questionnaire survey. For instance, an extensive
26 literature was conducted to identify various barriers influencing BIM full implementation in
27 AEC firms and various ways forward to improving BIM adoption among AEC firms in a wider
28 context. The barriers were identified from earlier studies (see Saxon, 2013; Zahrizan *et al.*, 2013;
29 Abubakar *et al.*, 2014; Gardezi *et al.*, 2014; Memon *et al.*, 2014; Liu *et al.*, 2015; Hosseini *et al.*,
30 2015) among others. Similarly, the ways forward to improving BIM adoption were as well
31 identified from important literature (see Alufohai, 2012; BuildSmart, 2013; Poole, 2014; Isa,
32 2015). The outcomes of both extensive review produced 20 barriers to BIM implementation and
33 10 ways forward to improving BIM adoption in AEC firms. Thereafter, both the 20 identified
34 barriers and 10 identified ways forward were utilized in designing the questionnaire survey. A
35 questionnaire survey was used to capture wider perceptions of the respondents. This approach is
36 widely supported by earlier studies, particularly in construction economics and management
37 studies. This is corroborated by Cheung (2009) that a questionnaire survey is an efficient
38 approach to collect data in a quantitative research. Notable earlier researchers in BIM studies
39 have largely adopted questionnaire survey (see Abanda *et al.*, 2015; Amuda-Yusuf, 2018;
40 Babatunde *et al.*, 2018) among others.
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45 The target population for this study comprised four different AEC firms to include: architectural
46 firms; facility management firms; quantity surveying firms; and structural engineering firms in
47 Lagos, Nigeria. The choice of the study area is due to the fact that a large percentage of AEC
48 firms are situated in Lagos state. Thus, the study area is adjudged appropriate to undertake a
49 survey and obtain the required data (Babatunde, 2015). The total lists of the aforementioned four
50 selected firms were obtained from their respective professional bodies in the study area. The lists
51 include only firms that paid their dues to their respective professional bodies to date as follows:
52 287 architectural firms; 57 quantity surveying firms; 78 structural engineering firms; and 18
53 facility management firms. For objectivity, 50 architectural firms, 50 quantity surveying firms,
54 50 structural engineering firms were purposively selected. Except for facility management firms,
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3 the entire 18 firms were selected due to their small population. This is resulting into a total of
4 168 firms as a sample size. Hence, a total of 168 questionnaires were self-distributed, which 107
5 questionnaires, representing 63.69% response rate were received and suitable for the analysis.
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7 Moreover, the questionnaire designed for this study was structured and multiple-choice type. For
8 instance, the questionnaire was divided into two broad sections. Section 'A' comprised the
9 background information of the respondents; this includes the AEC firm's category, highest
10 academic qualifications of the respondents, years of work experience, and designation of the
11 respondents. Section B was designed in relation to the barriers to BIM implementation and ways
12 forward to improve BIM adoption among AEC firms in the study area. For example, the
13 questions on the barriers to BIM implementation were asked on a five-point Likert scale rating
14 with 5 being the highest of the rating, where 5-Very high, 4- High, 3-Moderate, 2-low, and 1-
15 very low. Similarly, the questions on the ways forward to improve BIM adoption were asked on
16 a five-point Likert scale rating, where 5-Very high relevance, 4-High relevance, 3-Moderate
17 relevance, 2- low relevance, and 1-very low relevance. Moreover, reliability tests using the
18 Statistical Package for Social Science (SPSS V 21.0) was conducted on the research instrument
19 in this study. Thus, the questionnaire for this study was subjected to Cronbach's alpha test using
20 SPSS. The result indicated the reliability coefficient values of Cronbach's alpha for three
21 extracted factors obtained from the factor analysis. For instance, three factors for the BIM
22 barriers extracted from the factor analysis with their Cronbach's Alpha are as follows: Factor 1:
23 Weak top management support and BIM environment related issues; Factor 2: Cost of BIM
24 software and training; and Factor 3: Incompatibility, legal, contractual and culture related issues
25 with their values of Cronbach's alpha 0.934, 0.933 and 0.934 respectively. This approach was
26 supported by earlier studies (see Tuuli and Rowlinson, 2009). These values signified that the
27 questionnaire, including the Likert scale used was significantly reliable and indicate evidence of
28 internal consistency. This was supported by several earlier researchers that Cronbach's alpha
29 value of greater than 0.6 is reliable and acceptable (Pallant, 2007).
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34 The data obtained were analyzed using mean score, standard deviation, Kruskal-Wallis test, and
35 factor analysis. The mean score was employed for the ranking of identified 20 barriers to BIM
36 implementation and 10 identified ways forward to improving the BIM adoption in AEC firms.
37 Kruskal-Wallis test was undertaken to ascertain if there is a statistical significant difference in
38 the perceptions of four different groups (i.e. architectural firms, facility management firms,
39 quantity surveying firms, and structural engineering firms) in the aforementioned mean ranking.
40 Using Kruskal-Wallis test was widely encouraged by earlier researchers when the samples are
41 not less than three different groups with ordinal data (Zikmund, 2003; Fellows and Liu, 2008). In
42 addition, factor analysis was carried out to identify a small number of factor categorizations that
43 could be used to show relationships among a set of numerous inter-related variables (Pallant,
44 2010; Hair *et al.*, 2010). Thus, the factor analysis was undertaken on the 20 identified barriers to
45 BIM implementation with a view to determining the underpinning interactions or grouping that
46 might exist between the identified barriers. It is worthy to mention that factor analysis was not
47 conducted on the ways to improve BIM adoption because there are fewer identified variables,
48 precisely 10 variables. Thus, as a first step in conducting factor analysis, the suitability of the
49 survey data collected was examined using Kaiser-Meyer-Olkin (KMO) test and Barlett's test of
50 specificity (Pallant, 2010). Hence, the result of KMO value of 0.906; implied that the data
51 obtained were confirmed satisfactory for accurate completion of factor analysis (see Pallant,
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2010; Hair *et al.*, 2010). Similarly, Barlett's test of specificity value of 0.000; indicated that the correlation is strong enough to be accurate and suitable for conducting factor analysis. This was supported by the assertion of earlier researchers that Barlett's test of Sphericity value should be significant ($p < 0.05$) for the factor analysis to be considered appropriate (Field, 2005; Pallant, 2010; Hair *et al.*, 2010). After the data obtained were confirmed satisfactory, the factor analysis was undertaken on the identified 20 barriers to BIM implementation in AEC firms.

Results and discussion

The respondents' background information

Table II reveals the distribution of questionnaires to the respondents comprised architectural firms, facility management firms, quantity surveying firms, and structural engineering firms. As indicated in Table II, both the architectural firms and quantity surveying firms have higher rate of returns compared to other AEC firms in the category despite their tight schedules. This may be attributed to their interests in BIM research and their full awareness of BIM relevance to their professions.

>>>>>>>Insert Table II>>>>>>>>

Table III indicates the respondents' background information in each category of the firm. It shows that majority of the respondents have MSc (Masters Degree) with 60.7 per cent, followed by BSc (Bachelor's degree) with 25.2 per cent (see Table III). The years of work experience of the respondents showed that majority of the respondents have above 10 years work experience in their respective firms. In addition, the position of the respondents in their various firms indicated that 47.7 per cent of the respondents are managing director /chief executive officer, 35.5 per cent are senior staff, and 14.0 per cent are junior staff (see Table III). It is evident that the respondents have adequate academic background, appropriate knowledge and experience to provide adequate information.

>>>>>>>Insert Table III>>>>>>>>

Ranking of barriers to BIM implementation in AEC firms

Table IV indicates the survey response from four selected AEC firms comprised architectural firms, facility management firms, quantity surveying firms, and structural engineering firms. As indicated in Table IV, the results of the ranking of the 20 identified barriers to BIM implementation based on each AEC firm category are as follows:

Architectural firms: The top six ranked barriers to BIM implementation from respondents in architectural firms are: low level of BIM technical know-how and awareness; cost of BIM software; inaccessibility to suitable technology and framework; initial BIM huge capital outlays; lack of senior management support; and absence of appropriate BIM guidelines with their respective mean values of 4.27, 4.13, 4.08, 4.07, 4.04 and 4.02, respectively.

Facility management firms: The top six ranked barriers to BIM implementation from respondents in facility management firms include: absence of appropriate BIM guidelines; low level of BIM technical know-how and awareness; frequent power failure; lack of senior management support;

existing literature. For instance, Poole (2014) identified collaboration, training and promotion as the ways forward for BIM implementation in Hong Kong. Ezeokoli *et al.*, (2016) claimed that BIM should be made compulsory for all procurement processes and contracts, and setting up BIM council. In addition, the results of Kruskal-Wallis test revealed that except one (out of 10) identified ways forward to improve BIM adoption; there is no statistical significant difference in the perceptions of the four respondents groups.

Factor analysis on the barriers to BIM implementation in AEC firms

The factor analysis was undertaken on the identified 20 barriers to BIM implementation in AEC firms. However, factor analysis was not conducted on the ways to improve BIM adoption because there are fewer identified variables, precisely 10 variables. Thus, as shown in Table VI, the data obtained were confirmed satisfactory with Kaiser-Meyer-Olkin (KMO) value of 0.906 and Barlett's test of specificity value of 0.000 (see Pallant, 2010; Hair *et al.*, 2010). Notable earlier researchers in BIM studies supported this approach (see Memon *et al.*, 2014; Ozorhon *et al.*, 2016; Oduyemi *et al.*, 2017; Amuda-Yusuf, 2018) among others.

>>>>>>>Insert Table VI>>>>>>>>

In this study principal component analysis (PCA), eigenvalue, and the scree plot were used as decision criteria (see Pallant, 2010; K'Akumu *et al.*, 2013). This study adhered to the rule, as shown Table VII, that only three factors have eigenvalue greater than 1.0 were retained. In addition, as indicated in Table VII, since both Cronbach's alpha test and factor loading for each identified BIM barrier exceeded the threshold of 0.70 and 0.40 respectively, they were accepted with other scales being valid and reliable for this study (see Kline, 2002; Pallant, 2007, 2010; Brown, 2009). *As shown in Table VII, as supported by Tuuli and Rowlinson (2009), the values of Cronbach's alpha for each of the three factors of BIM barriers extracted from the factor analysis are 0.934, 0.933 and 0.934 respectively.*

>>>>>>>Insert Table VII>>>>>>>>

These three factors were further confirmed through scree plot as recommended by earlier researchers (see Pallant, 2010).

>>>>>>>Insert Figure I>>>>>>>>

Table VII shows the extracted three factors with the total variance explained of 64.638 per cent. The three main factors extracted (see Table VII) are interpreted as follows:

- Factor 1: Weak top management support and BIM environment related issues
- Factor 2: Cost of BIM software and training
- Factor 3: Incompatibility, legal, contractual and culture related issues

Factor 1: Weak top management support and BIM environment related issues: This factor amounts to 22.285 per cent (see Table VII) of the total variance of barriers to BIM

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3 implementation in AEC firms. This factor has seven main items as follows: lack of senior
4 management support; level of BIM technical know-how and awareness; inaccessibility to
5 suitable technology and framework; lack of enabling environment; individual perception / point
6 of view; absence of appropriate BIM guidelines; and competing initiatives respectively. These
7 seven items have high factor loadings: 0.805, 0.792, 0.753, 0.724, 0.654, 0.644, and 0.617,
8 respectively (see Table VII). This study finding confirmed the assertion of Enegbuma *et al.*
9 (2014); Liu *et al.* (2015) and Akerele and Etiene (2016) that inadequacy of appropriate skills
10 and technical know-how in the usage of BIM is one of the major barriers to the adoption of BIM
11 in their individual nations, among others. Thus, this study recommends that firms' top managers
12 and decision makers should encourage the usage of BIM in their day-to-day activities and
13 provide BIM-related workshops and seminars for their staff to acquire appropriate BIM skills
14 and technical know-how.
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18 *Factor 2: Cost of BIM software and training:* This factor amounts to 21.689 per cent (see Table
19 VII). The five items of cost of BIM software and training as a factor include: cost of software;
20 cost of training; initial BIM huge capital outlays; lack of supply chain buy-in; and lack of
21 demand by clients. The factor loadings for the items are: 0.822, 0.796, 0.700, 0.637, and 0.636
22 respectively. These findings indicate that the huge financial implication of procuring BIM
23 software and associated training of staff required are considered as a major barrier to BIM
24 adoption and implementation in AEC firms, it is on this premise that this study recommends
25 that the cost of BIM software and training of staff should be subsidize by the government and
26 other approved authorities.
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30 *Factor 3: Incompatibility, legal, contractual and culture related issues:* This factor has 20.663
31 per cent (see Table VII) of the total variance of barriers to BIM implementation in AEC firms.
32 The items of this factor are: incompatibility and interoperability problems; legal and contractual
33 constraints; lack of support from policy makers; staff resistance; scale of culture change
34 required, frequent power failure; and poor internet connectivity. The factor loadings for these
35 items include: 0.792, 0.743, 0.742, 0.672, 0.668, 0.597, and 0.586 respectively. This study
36 finding confirmed the assertion of Abdullah *et al.* (2016) that legal and contractual constraints
37 are barriers to BIM implementation. Autodesk (2011) also reported that computability of digital
38 information and meaningful data interoperability are barriers to BIM implementation. Against
39 this backdrop this study recommends that compatible and interoperable compliant BIM
40 software should be develop by construction program developers and the government should
41 make suitable construction related policies with a view to eradicating legal and contractual
42 constraints that plagues BIM adoption in the construction industry at large.
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46 **Conclusions**

47 BIM has much potential to improve the effectiveness of construction works with respect to
48 design, construction and maintenance. Even though there are various factors hindering the
49 progress of BIM implementation in AEC firms. Hence, this study assessed the barriers to BIM
50 implementation and way forward to improve its adoption in AEC firms. The study identified 20
51 barriers to BIM implementation and identified 10 ways forward to improve BIM adoption in
52 AEC firms. The relative importance of both the identified barriers and the ways forward were
53 gauged from four different AEC firms comprised architectural firms, facility management firms,
54 quantity surveying firms, and structural engineering firms in Nigeria. The analysis of the total
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mean score values for the identified 20 barriers to BIM implementation ranges from 3.28 to 4.20. This indicated that all the respondents considered these 20 identified barriers to BIM implementation as serious barriers in the Nigerian AEC firms. Therefore, this study concludes that there are more barriers to BIM implementation in the Nigerian AEC firms, which is a true reflection of developing countries at large. In addition, the study revealed the overall top six ranked barriers to BIM implementation in AEC firms as follows: low level of BIM technical know-how and awareness; inaccessibility to suitable technology and framework; initial BIM huge capital outlays; absence of appropriate BIM guidelines; lack of senior management support; and lack of enabling environment. Similarly, the overall mean values of the 10 identified ways forward to improve BIM adoption in AEC firms indicated total mean values ranging from 3.97 to 4.64; this implied that all the 10 identified ways forward are important. In addition, the overall top five ranked ways forward to improve BIM adoption in AEC firms are: incorporation of BIM to academic curriculum; improve BIM awareness and understanding; provision of training by employers; reduction in cost of implementing BIM; and developing BIM guidelines. The study further revealed the Kruskal-Wallis test, which indicated that except for one (out of 20) identified barriers, and one (out of 10) identified ways forward; there is no statistical significant difference in the perceptions of respondents from four different AEC firms. This implied that there is high degree of agreement among the four groups of respondents. This finding is not surprising because the respondents are fully aware and have a common understanding on the barriers to BIM implementation and possible ways forward to improving BIM adoption in AEC firms. In addition, the study showed the result of factor analysis that grouped the 20 identified barriers into three main factors to include: weak top management support and BIM environment related issues; cost of BIM software and training; and incompatibility, legal, contractual, and culture related issues. Based on these findings, the study recommends as follows:

- massive awareness of BIM by professional bodies, government agencies, and non-governmental organizations both locally and internationally;
- professional bodies should continue organizing BIM-related workshops and seminars for their members to further acquire appropriate BIM skills and technical know-how;
- the cost of BIM software and training of staff should be subsidize by the government and other approved authorities;
- appropriate government policies and guidelines that support BIM implementation should be in place in developing countries as whole; and
- BIM concept should be incorporated into academic curricula of architecture, engineering, and construction related disciplines in higher education

The significance of this study cannot be over-emphasized due to BIM relevance to the construction stakeholders and researchers at large. For instance, the study findings would inform the decisions of the construction stakeholders to make some policy recommendations capable of positively influencing the full implementation of BIM in AEC firms.

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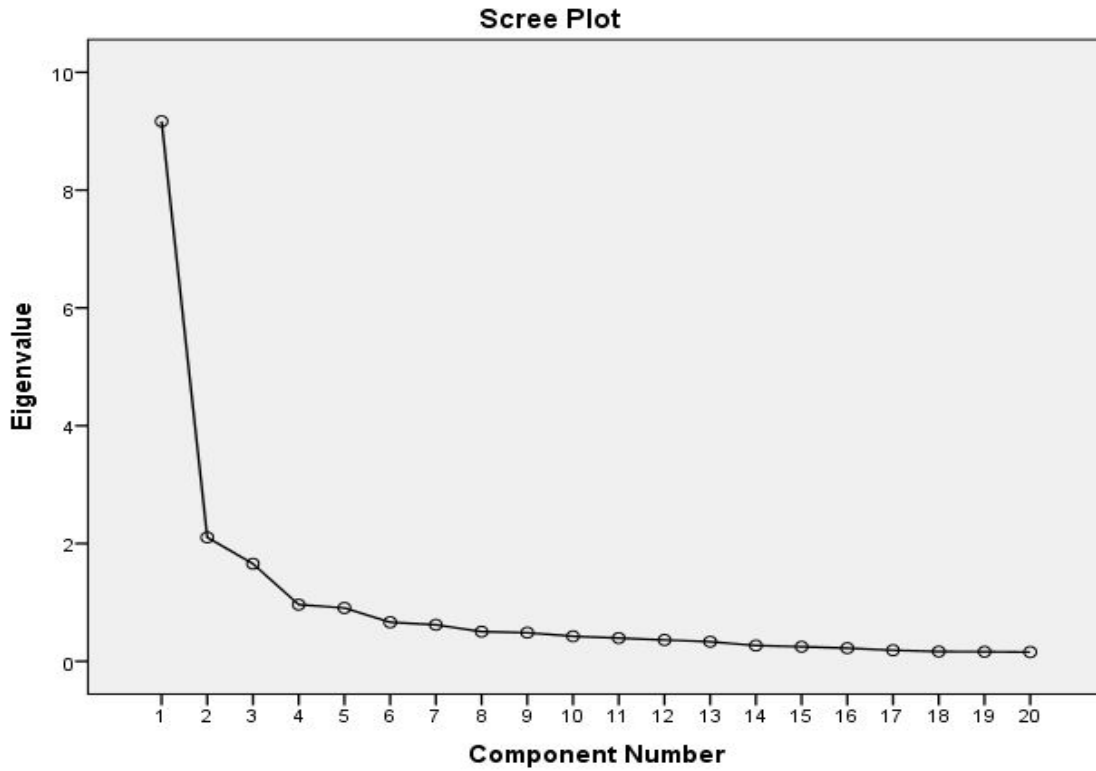


Figure I: Scree plot showing extracted factors on 20 identified barriers to BIM implementation in AEC firms

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Table I: Identified barriers to BIM implementation in AEC firms

Code	BIM Barriers	
BA01	Lack of senior management support	Zahrizan <i>et al.</i> , 2013; Kerosuoa <i>et al.</i> , 2015; Kori and Arto, 2015; Ezeokoli <i>et al.</i> , 2016
BA02	Low level of BIM technical know-how and awareness	Latiffi <i>et al.</i> , 2013; Zahrizan <i>et al.</i> , 2013; Enegbuma <i>et al.</i> , 2014; Liu <i>et al.</i> , 2015; Akerele and Etiene, 2016
BA03	Inaccessibility to suitable technology and framework	Hergunsel, 2011; Zahrizan <i>et al.</i> , 2013; Obiegbu and Ezeokoli, 2014; Ezeokoli <i>et al.</i> , 2016
BA04	Individual perception/ point of view	Zahrizan <i>et al.</i> , 2013; Liu <i>et al.</i> , 2015
BA05	Absence of appropriate BIM guidelines	Zahrizan <i>et al.</i> , 2013; Abubakar <i>et al.</i> , 2014; Akerele and Etiene, 2016; Ezeokoli <i>et al.</i> , 2016
BA06	Lack of enabling environment	Bernstein and Pittman, 2014; Enegbuma <i>et al.</i> , 2014; Hosseini <i>et al.</i> , 2015
BA07	Initial BIM huge capital outlays	Young <i>et al.</i> , 2008; Memon <i>et al.</i> , 2014; Gardezi <i>et al.</i> , 2014
BA08	Lack of vision of benefits	Coates <i>et al.</i> , 2010; Arayici <i>et al.</i> , 2011; Lee <i>et al.</i> , 2012; Memon <i>et al.</i> , 2014
BA09	Cost of training	Yan and Damian, 2008; Coates <i>et al.</i> , 2010; Azhar, 2011; Efficiency and Reform Group, 2011; Crotty, 2012
BA10	Cost of software	Giel <i>et al.</i> , 2010; Thompson and Miner, 2010; Azhar, 2011; Efficiency and Reform Group, 2011; Crotty, 2012; Lee <i>et al.</i> , 2012
BA11	Scale of culture change required	Jordani, 2008; Mihindu and Arayici, 2008; Watson, 2008; Yan and Damian, 2008
BA12	Competing initiatives	Cabinet Office, 2012
BA13	Lack of supply chain buy-in	Aouad <i>et al.</i> , 2006
BA14	Staff resistance	Yan and Damian, 2008; Arayici <i>et al.</i> , 2009
BA15	Legal and contractual constraints	Christensen <i>et al.</i> , 2007; Arayici <i>et al.</i> , 2009; Chao-Duivis, 2009; Azhar, 2011; BIM Industry Working Group, 2011; Oluwole, 2011; Race, 2012
BA16	Poor internet connectivity	Oladapo, 2007; Onungwa <i>et al.</i> , 2017; Babatunde and Ekundayo, 2019
BA17	Frequent power failure	Abubakar <i>et al.</i> , 2014; Babatunde and Ekundayo, 2019
BA18	Lack of demand by clients	BCIS, 2011; Zuhairi <i>et al.</i> , 2014; Saleh, 2015; Wang <i>et al.</i> , 2015
BA19	Incompatibility and interoperability problems	Autodesk, 2002; Arayici <i>et al.</i> , 2009; Arayici <i>et al.</i> , 2011
BA20	Lack of support from policy makers	Wang <i>et al.</i> , 2015

Table II: Distribution of questionnaires to the respondents

AEC firms	Questionnaire administered	Questionnaire retrieved	%
Architectural firms	50	48	96
Facility management firms	18	9	50
Quantity surveying firms	50	37	74
Structural engineering firms	50	13	26
Total	168	107	63.69

Table III: Background information of the respondents

Respondent	AEC firms {Freq. (%)}			
	Architectural firms	Facility management firms	Quantity surveying firms	Structural engineering firms
<i>Profile</i>				
<i>Academic qualification</i>				
ND (National Diploma)	-	1 (11.1)	-	1 (7.7)
HND(Higher National Diploma)	2 (4.2)	3 (33.3)	4 (10.8)	1 (7.7)
B.Sc./B.Tech.	-	4 (44.4)	18 (48.6)	6 (46.2)
M.Sc.	45 (93.8)	1 (11.1)	15 (40.5)	4 (30.7)
PhD	1 (2.08)	-	-	1 (7.7)
Total	48 (100)	9 (100)	37 (100)	13 (100)
<i>Years of work experience</i>				
1-5 years	1 (2.08)	3 (33.3)	16 (43.2)	2 (15.4)
6-10 years	2 (4.2)	5 (55.5)	10 (27.0)	5 (38.5)
11-15 years	8 (16.7)	1(11.1)	2 (5.4)	5 (38.5)
16-20 years	15 (31.3)	-	4 (10.8)	1 (7.69)
21-25 years	4 (8.3)	-	1 (2.7)	-
26-30 years	18 (37.5)	-	4 (10.8)	-
Total	48 (100)	9 (100)	37 (100)	13 (100)
<i>Designation of the respondents</i>				
Junior staff	2 (4.2)	1(11.1)	10 (27.0)	2 (15.4)
Senior staff	7 (14.6)	2 (22.2)	24 (64.9)	5 (38.5)
Technical staff	-	-	1 (2.7)	1 (7.69)
Contract staff	-	1(11.1)	-	-
Managing director	39 (81.3)	5 (55.5)	2 (5.4)	5 (38.5)
Total	48 (100)	9 (100)	37 (100)	13 (100)

Table IV: Ranking of barriers to BIM implementation in AEC firms

BIM barriers	Architectural firm			Facility management firm			Quantity surveying firm			Structural engineering firm			Total Mean	Total Rank	Kruskal-Wallis Sig
	Mean	S.D	Rank	Mean	S.D	Rank	Mean	S.D	Rank	Mean	S.D	Rank			
BA01. Lack of senior management support	4.04	0.82	5	3.88	1.05	4	4.03	0.82	8	4.00	0.90	6	3.99	5	0.913
BA02. Low level of BIM technical know-how and awareness	4.27	0.98	1	3.97	1.09	2	4.52	0.78	1	4.04	1.00	4	4.20	1	0.255
BA03. Inaccessibility to suitable technology and framework	4.08	0.99	3	3.73	1.19	10	4.12	0.84	5	4.20	0.98	1	4.03	2	0.591
BA04. Individual perception/ point of view	3.79	0.95	14	3.75	0.84	9	3.77	0.93	14	3.98	0.97	8	3.82	10	0.941
BA05. Absence of appropriate BIM guidelines	4.02	0.98	6	4.03	1.12	1	4.04	0.94	7	4.00	1.13	7	4.02	4	0.973
BA06. Lack of enabling environment	3.99	0.98	8	3.48	0.99	13	4.18	0.84	4	4.10	0.95	3	3.94	6	0.249
BA07. Initial BIM huge capital outlays	4.07	1.05	4	3.81	1.01	6	4.36	0.83	3	3.87	0.99	9	4.03	3	0.219
BA08. Lack of vision of benefits	4.00	1.05	7	3.55	1.06	12	3.90	0.99	11	4.16	0.89	2	3.90	8	0.609
BA09. Cost of training	3.94	0.94	10	3.21	0.59	16	4.05	0.84	6	3.52	0.89	17	3.68	15	0.097
BA10. Cost of software	4.13	0.96	2	3.00	0.59	20	4.49	0.80	2	3.60	0.96	16	3.81	11	0.001*
BA11. Scale of culture change required	3.82	0.95	13	3.15	0.69	18	3.88	0.88	12	3.68	0.85	14	3.63	16	0.350
BA12. Competing initiatives	3.71	0.95	17	3.15	0.69	19	3.58	0.81	19	3.73	0.98	13	3.54	18	0.665
BA13. Lack of supply chain buy-in	3.73	0.89	15	3.21	0.59	17	3.92	1.06	10	3.40	0.95	19	3.57	17	0.431
BA14. Staff resistance	3.40	0.98	20	3.22	0.83	15	3.61	1.02	18	3.65	1.00	15	3.47	19	0.786
BA15. Legal and contractual constraints	3.47	0.97	19	3.34	0.64	14	3.21	0.96	20	3.11	0.79	20	3.28	20	0.573
BA16. Poor internet connectivity	3.91	1.04	11	3.77	1.10	8	3.70	1.16	15	3.49	0.95	18	3.72	14	0.615
BA17. Frequent power failure	3.96	1.09	9	3.90	1.27	3	3.67	1.11	16	3.84	1.14	10	3.84	9	0.770
BA18. Lack of demand by clients	3.73	1.11	16	3.71	1.05	11	3.81	1.19	13	3.77	1.08	12	3.76	12	0.986
BA19. Incompatibility and interoperability problems	3.65	1.04	18	3.81	1.01	7	3.67	1.01	17	3.82	0.97	11	3.74	13	0.895
BA20. Lack of support from policy makers	3.86	1.11	12	3.88	1.05	5	3.94	1.08	9	4.02	1.06	5	3.93	7	0.943

Note: *Significant at 5%

Table V: Ranking of the ways forward to improve BIM among AEC firms

Ways forward	Architectural firm			Facility management firm			Quantity surveying firm			Structural engineering firm			Total Mean	Total Rank	Kruskal Wallis Sig
	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank			
W01. Incorporation of BIM to academic curriculum	4.71	0.61	1	4.39	1.10	2	4.73	0.59	2	4.72	0.66	1	4.64	1	0.743
W02. Improve BIM awareness and understanding	4.64	0.66	2	4.47	0.90	1	4.72	0.65	3	4.41	0.71	3	4.56	2	0.393
W03. Outsourcing BIM experts	3.99	0.86	9	4.35	0.90	3	4.36	0.75	9	4.29	0.93	5	4.25	8	0.184
W04. Provision of training by employers	4.34	0.80	4	4.35	0.90	4	4.78	0.53	1	4.48	0.87	2	4.49	3	0.030*
W05. Government Legislation supporting the use of BIM	4.17	0.91	8	4.22	0.87	7	4.55	0.69	5	4.22	0.83	6	4.29	6	0.137
W06. Developing BIM guidelines	4.22	0.78	7	4.35	0.90	5	4.52	0.61	6	4.16	0.89	7	4.31	5	0.190
W07. Reduction in cost of implementing BIM	4.47	0.78	3	3.85	0.79	10	4.64	0.68	4	4.31	0.85	4	4.32	4	0.068
W08. Setting up BIM council	3.89	0.99	10	4.09	0.82	8	3.93	0.96	10	3.98	1.22	10	3.97	10	0.821
W09. Compulsory use of BIM for all procurement and contract	4.24	1.01	6	4.35	0.90	6	4.37	0.80	8	4.16	1.20	8	4.28	7	0.589
W10. Provision of appropriate technology and infrastructure	4.32	0.87	5	4.00	0.89	9	4.49	0.67	7	4.00	0.90	9	4.20	9	0.149

Note: *Significant at 5%

Table VI: KMO and Bartlett's sphericity test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.906
Bartlett's Test of Sphericity	Approx. Chi-Square	1399.054
	Df	190
	Sig.	0.000

Table VII: Principal factor extraction, varimax rotation and total variance explained on 20 identified barriers to BIM implementation in AEC firms

Principal factors with their components	Cronbach's Alpha	Factor loading	Total variance	Initial Eigenvalues % of Total variance explained	Cumulative % of variance explained
<i>Factor 1: Weak top management support and BIM environment related issues</i>					
1. Lack of senior management support		0.805			
2. Level of BIM technical know-how and awareness		0.792			
3. Inaccessibility to suitable technology and framework		0.753			
6. Lack of enabling environment	0.934	0.724	9.168	22.285	22.285
4. Individual perception/ point of view		0.654			
5. Absence of appropriate BIM guidelines		0.644			
12. Competing initiatives		0.617			
8. Lack of vision of benefits		0.464			
<i>Factor 2: Cost of BIM software and training</i>					
10. Cost of software		0.822			
9. Cost of training		0.796			
7. Initial BIM huge capital outlays	0.933	0.700	2.103	21.689	43.974
13. Lack of supply chain buy-in		0.637			
18. Lack of demand by clients		0.636			
<i>Factor 3: Incompatibility, legal, contractual and culture related issues</i>					
19. Incompatibility and interoperability problems		0.792			
15. Legal and contractual constraints		0.743			
20. Lack of support from policy makers	0.934	0.742	1.656	20.663	64.638
14. Staff resistance		0.672			
11. Scale of culture change required		0.668			
17. Frequent power failure		0.597			
16. Poor internet connectivity		0.586			
Note: Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization; Rotation converged in six iterations					