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Comparative analysis of drivers to BIM adoption among AEC firms in developing countries: A case of Nigeria

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Abstract

Purpose – Building information modelling (BIM) adoption is vital to productivity and competitive nature of the construction sector. However, BIM adoptions have not been generally embraced by many Architecture, Engineering, and Construction (AEC) firms, particularly in developing countries; and studies that investigate the important drivers to BIM adoptions among construction professionals through quantitative approach are limited. The study purpose is to address the aforementioned gap.

Design/methodology/approach – The study used a literature review, a pilot study and a questionnaire survey. The primary data were carried out using structured questionnaire distributed to the four different, selected BIM adopters' AEC firms. These comprised architectural firms, facility management firms, quantity surveying firms and structural engineering firms in Lagos, Nigeria. Data obtained were analyzed using mean score, standard deviation, Kruskal-Wallis test, and factor analysis.

Findings – The study identified 23 drivers to BIM adoption and the relative importance of the identified drivers was gauged from each selected BIM adopters' AEC firm category. The result of the Kruskal-Wallis test showed that there is no statistically significant difference in the perceptions of the four selected AEC firms in the mean ranking of the identified 23 drivers to BIM adoption. The findings from factor analysis categorized the identified drivers into two major factors to include: cost and time savings, and improved communication; and BIM awareness and government supports.

Practical implications – The study empirically identified important drivers to BIM adoption which will be useful for construction stakeholders to formulate strategies to adopt the full implementation of BIM in the Nigerian AEC firms and other developing countries. Also, this study is very important as it identified, analyzed, and compared the drivers to BIM adoptions from four different AEC firms; thereby providing robust and more reliable findings.

Originality/value – The study findings would inform the decisions of policy makers and construction stakeholders to make some policy recommendations capable of positively influencing the widespread adoption of BIM in AEC firms and construction industry at large. This study is important because the studies that comparatively and empirically analyzed BIM drivers in AEC firms are rare, particularly in developing countries. Hence, this study could be used to benchmark future studies in developing countries.

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

Paper type Research paper

Introduction

The requirement for a more articulate exchange of information among construction participants in order to tackle challenges related to fragmentized project delivery, excessive expenditure, compromised quality and ineffective facility management of projects evident in the traditional method of procurement prompted the emergence of Building Information

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Modelling (BIM). The act of applying and maintaining a composed digital representation of information all over various phases of the construction project are done through BIM (Eastman and sacks, 2011). Generally, all over the world, with the adoption and implementation of BIM, the construction industry is transferring rapidly. The design processes as well as the construction of buildings are changing. For instance, Hassan and yolle (2009) claimed that the 3D modelling expands to scheduling and sequencing 4D, cost estimating 5D, sustainable design also termed Green design 6D and facility management 7D. Depending on the agreement between the clients, architects, engineers, manufacturers, building services, contractors and other consultants, BIM are seen as a new approach to design. Becerik-Gerber and Rice (2010) asserted that BIM involves processes that can assist the construction industry to increase its efficiency via consistent communication and cooperation among the project participants from commencement to the execution of projects. Abubakar *et al*. (2014) stated that BIM has much potential to improve the effectiveness of construction works with respect to design, construction and maintenance.

Olugbenga and Aina (2016) claimed that due to the inherent capabilities of BIM, governments of developed countries are encouraging the adoptions of BIM in their construction projects. For instance, almost one-half of the construction firms in the United States are already implementing BIM in their practices. An on-line survey on the extent to which AEC firms uses BIM in the US showed that fifty-six percent of the firms used BIM, applied it on fifty percent of their jobs, with just thirty-four percent of firms rarely using it (McGraw, 2010). The government of the United Kingdom had successfully integrated BIM in the practices of their construction sector, has recorded substantial savings via the usage of BIM and has identified BIM as a relevant “instrument” in assisting the government to accomplish its aim of fifteen to twenty percent savings on project cost unfailingly by the year 2015 (UK BIM Strategy Report, 2012). In addition, UK BIM Strategy Report (2012); Wong *et al*.(2009) and BuildSmart (2012) reported that several governments of developed countries to include the UK, US, and Australia among others have set up strategies for BIM implementation in their construction works which has led to rapid BIM adoption. For instance, the US has been recognized as a leading country in the BIM implementation (McGraw-Hill, 2014). Moreover, BuildSmart (2011) reported that the ministry of works and infrastructure in Singapore initiated BIM strategic plan in the year 2010 solely to ensure that eighty percent of the construction firms had undertaken BIM by the year 2015. However, most developing countries have been reported to be slow with the adoption and implementation of BIM (Olawumi and Chan, 2019).

In Nigeria, over the years various studies have been carried out on BIM implementation and adoption among construction professionals. For example, Alufohai, (2012) examined BIM adoption in the Nigerian construction industry and found out that adopting BIM among the Nigerian private and public sector clients as well as among various construction professionals (architects, quantity surveyors, civil engineers etc.) have been very slow. This can be seen as been unfortunate as BIM has extraordinary potentials to improve effectiveness, minimize disputes, and cost savings as well as checking corruptions. Ugochukwu *et al*. (2015) studied the status of BIM in construction projects and found that BIM is yet to be fully embraced in the Nigerian building industry. This is because the use of BIM as an information system in the construction industry is a real reengineering resource to the sector. Onungwa *et al*. (2017) explored BIM and collaboration in the Nigerian construction industry and found out that one of the major uses of BIM is its collaboration, efficiency improvement and communication potential. However, architectural firms have adopted BIM mostly for sketch and presentation of designs in Nigeria. Akerele and Etiene (2016) examined the assessment of the awareness

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and limitations on the usage of BIM and established low awareness on the usage of BIM. Marcus *et al*. (2015) examined BIM in the Nigerian construction industry and concluded that there is a low level of knowledge of BIM which is related to the low utilization among the stakeholders.

Existing studies on BIM in Nigeria (see Alufohai, 2012; Abubakar *et al*. 2014; Marcus *et al*., 2015; Ugochukwu *et al*., 2015; Akerele and Etiene, 2016; Hamma-adama *et al*., 2017; Onungwa *et al*., 2017; Babatunde *et al*., 2018) among others focussed on BIM awareness, adoption, implementation, and challenges both from the industry and academia perspectives. Few of these studies that examined the drivers to BIM adoption (see Babatunde *et al*., 2018) paid attention to the drivers to BIM incorporation into quantity surveying profession from academia and students' perspectives; hence the study (Babatunde *et al*., 2018) failed to examine the phenomenon from industry stakeholders' perspective. Being aware of this gap, this study aimed at investigating the important drivers to BIM adoptions among AEC firms through quantitative approach. It is in pursuance of this aim that four different AEC firms comprised architectural firms, facility management firms, quantity surveying firms and structural engineering firms that already adopted BIM for their practices are considered as respondents in this study.

Literature review

Drivers to BIM adoption in the construction industry

Over the years, the matters relating to BIM has reached a widespread popularity in the construction industry. In improving the construction industry productivity, BIM is seen as a driver by ensuring collaboration between all stakeholders and effective communication from the start of the construction project even to its completion. Some selected drivers to BIM adoptions; particularly in developed countries as identified by previous studies are briefly discussed as follows:

Government pressure

Recent reports show that several governments of developed countries to include the UK, US and Australia among others have set up strategies for BIM implementation in their construction works which has led to rapid BIM adoption (Wong *et al*., 2009; UK BIM Strategy Report, 2012; BuildSmart, 2012). BIM related policies made by the governments of various developed countries place the construction industry under pressure to offer maximum value for the client's money, viable design and durable construction works which are associated with the usage of BIM and these policies compel the construction industry to participate in the adoption and implementation of BIM with a view of procuring public financed projects (Arayici *et al*., 2011). It is not surprising that BIM adoptions are of increase in most developed countries. However, Alufohai (2012) argued that the extent of BIM adoption is relatively low in countries where there are no government policies in place to encourage BIM adoption.

Urge to meet client's needs and competitive nature of the industry

The nature of the construction industry is highly competitive of which the economic recession have not in any way alleviated its negative effects coupled with acute shortage of funds, alternating high costs and the urge to get maximum value for money. The promoters of building works are making demands on the contractors not to merely establish the inherent ability of BIM but to show evidences of previously completed projects that have been successfully delivered through the implementation of BIM (Eadie *et al*., 2013). Also, Eadie

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et al (2013) suggested that as building client get updated in their knowledge of BIM; it is expected of project managers to aim at the implementation of BIM in their practices before the deadline set by the government with the aim of developing expertise in the usage of BIM. This is regarded as one of the most important drivers to the adoption of BIM by architectural firms (Coates *et al*., 2010). However, Liu *et al*. (2010) claimed that others factors, mostly external factors also have significant roles in the adoption of BIM.

Improvement of capacity to provide whole life cycle value to client

Azhar *et al*. (2011) emphasized that most current BIM software and products have inherent abilities to analyze project's schedule and cost among others. It can be utilized collectively by construction stakeholders for the delivery of project that give realistic whole life value to building owners. There is a need to reduce waste, enhance productivity and quality of construction works. This might be responsible for the shift from initial capital cost to securing whole life costing (Eadie *et al*., 2013). Barlish and Sullivan (2012) and Deutsch (2011) asserted that the effects of design on the operating cost of construction work is substantial and enhances productivity which offers financial savings to the building owner. Eadie *et al* (2013) opined that the four dimensional (4D) modelling which comprises of BIM and time can be used for the management of facilities, ascertain demolition methods and outright decommissioning of projects or for inventive proposal that have multipurpose usage. This is supported by Grilo and Jardim-Goncalves (2010) that when such models are implemented by construction professionals who are knowledgeable and have developed required skills in the usage of BIM, this makes it a suitable tool for the delivery of whole life value.

Reformation of design activities and improvement of design quality

Deutsh (2011) stated that the process of design in the outline plan of work in the United Kingdom which ranges from the concept stage to the technical design stage involves various activities such as production of designs, and presentation of designs to the building owners for approval. However, BIM models can provide virtual representations that help to inform the decisions of the clients at the design stage; and thereby minimizing the possibility of variations in the post contract stage of the project (Eastman *et al*., 2011). Also, Azhar *et al*. (2008) and Bentley (2012) asserted that real time and electronically prepared drawings and design can be easily verified on the computer screen. This can be actualized owing to the parametric nature of BIM as opposed to line diagram of Computer Aided Drawings and in addition there is possibility of replicating basic elements of building on screen from the collection of already finished models thereby enhancing quick and accurate preparation of conceptual design (Eadie *et al.*, 2013).

Incorporation of health and safety in the construction process

BIM model permit the virtual view of construction processes, but it is however not needed if necessary information and health and safety executives' reports concerning the site can be obtained (Eadie *et al.*, 2013). They further stated that the same way BIM can be used for ascertaining the building energy cost and whole life value, it is also used to carry out simulation of the construction process which will inevitably enable the studying of the site layout plan in order to minimize the occurrence of accident or injury which can then be interpreted via either oral or written communication to work men who will carry out the real work on site. In so doing the construction site can be made safer for construction activities (Kiviniemi *et al*., 2011).

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The need to enhance communication with workmen

BIM assists contractors to improve on their interaction with workmen. Four dimensional BIM (BIM + Time) has the inherent ability to show electronically the virtual order of construction on screen and it is usually deployed by architect and planners to relate the order of operations that workmen are expected to carry out on site (Sacks *et al*., 2009). This is important as it helps even unskilled workmen to have a feel of the construction methodology which will inevitably fast track the process of work on site. Tutt *et al*. (2011) stated that the involvement of workmen from different locality has necessitated the increasing need for construction interpreters with visual representation of the project. Eadie *et al.* (2013) affirmed that workmen might be able to proffer solution to some buildability issues on site and as such BIM can enhance effective cooperation through communication and visual representation of the project.

The need to secure more financial savings and monitoring

BIMhub (2012) and Crotty (2012) reported that the traditional method of presenting design information to contractors is subject to errors or omissions, which will inevitably provide contractors with inadequate information. This may be accompanied by *"Requests for Information"* (RFIs) (Eadie *et al*., 2013). Dickinson (2010) argued that RFIs are responsible for un-envisaged delays and may necessitate working on the design again, which can lead to excessive expenditure for the project. However, RFIs can be reduced to the barest minimum through the usage of a single BIM model that contains the object information of the project by all the project participants (Azhar *et al*., 2008; Deutsch, 2011; Barlish *et al*., 2012). Applied software (2009) reported that RFIs was minimized by thirty-two percent through the usage of BIM on the Mortenson Group. Eadie *et al* (2013) affirmed that the inherent capability of BIM to produce automatically costed estimate of changes in design is not limited to prime cost (cost of material, labour, and plant) of the project but also include recognition of construction period for weather analysis, interval between work packages and even integrate a sum for contingency, thus a contractor who is conversant with the usage of BIM can quickly generate realistic estimates and use it as a determinant for cross-checking the cost implications of their decisions on a project.

The need for timely delivery

The need for planning, re-planning, forecasting of cost and time are necessary as the brief is further developed throughout the design stage of the project. However, if there are any changes to the design, there would be a meeting to that effect with the design team for necessary modification to the design which will be delivered to the contractor and quantity surveyor to estimate the probable cost of the project. This process may however be repeated until there is an harmonious relationship between the design and the probable cost but with the emergence of five dimension BIM (5D BIM+ Cost), the project participants such as the building owner, project manager, contractor and designers (architects and engineers) can now hold a meeting online at an agreed time to deliberate changes in the design and the cost can be modified instantly (Eadie *et al*., 2013). Similarly, Azhar *et al* (2008) asserted that BIM has the capability to reduce the time required as high as eighty percent to produce an estimate. It is therefore evident that the procedure of alteration and agreement of changes in design, cost estimates resulting from changes in design, preparation and keeping up to date of records and program, can be drastically reduce from duration in days to hours (Eastman *et al*., 2011).

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The need for more precise order of construction and clash detention

Four dimensional BIM (BIM + Time) has the capability to be used for generating comprehensive procedure for construction projects (BIMhub, 2012). BIM can provide the visual representation of the building elements in relation to time (Deutch, 2011; Eastman *et al.*, 2011). In addition, Leite *et al.* (2009) claimed that other than visual representation, BIM can also be used for generating animations and computer simulations of clashes between various components of the building. Traditionally, clashes in construction works are only discovered during the construction stage of the project and actions to remedy errors found can be very costly (Azhar *et al.*, 2008; Azhar, 2011). Substantial time and financial savings can be realized via proper scheduling of works (Azhar, 2011). When construction works are behind schedule, it has detrimental effect on the extent to which material will be ordered, pre-fabricated and the delivery of the required building components (Eadie *et al.*, 2013). Moreover, Azhar (2011) and Eastman *et al.* (2011) argued that the four dimensional BIM provides comprehensive scheduling that can correctly forecast the duration for individual task or activity, successor activity alongside with the required resources; and also allows the incorporation of slack, delivery schedule and severe climate. Azhar *et al* (2008) stated that the detection of clashes can save up to ten percent of the contract sum and shorten duration of project by seven percent. These savings are gradually moving towards the envisaged fifteen percent of project savings via BIM as laid down by the government of United Kingdom (Efficiency and Reform Group, 2011).

Enhancing increased pre-fabrication

Eadie *et al.* (2013) claimed that the usage of pre-fabricated building components and assembling them on-site saves both time and cost. Therefore, modular building contractors can utilize BIM in their practices owing to its ability to generate comprehensive information and model concerning the manufactured building components which will certainly increase quality output and limit "Requests for Information" (Eastman *et al.*, 2011). This is affirmed by Nawari (2012) that the benefits of BIM for the pre-fabrication of building components off site include timely delivery, affordable cost of fabrication and safety.

The need for effective facilities management of completed projects

Customarily, the transfer of ownership of a completed project from the contractor to the client entails the collection of revised set of drawings, which shows all the variations made in the specification and working drawings during the construction phase, user and maintenance guides and warranty (Crotty, 2012). Instead of out-rightly eradicating the traditional process of transfer of ownership, the BIM model of the project can be connected to a current facilities management system to generate precise and harmonizing real-time information, which allows quick, correct and effective facilities management (Zhang *et al.*, 2009). Also, Lewis *et al.* (2010) claimed that seventy percent of reactionary maintenance can be saved by facility manager as long as accurate information concerning the element of the building are properly inputted into the BIM model.

In summary, the identified drivers from previous studies are presented in Table I as follows:

>>>>>>>>Insert Table I>>>>>>>>>

It is evident from Table I that several studies have been conducted, particularly in developed countries on drivers to BIM adoption in construction industry, but limited study has been conducted in developing countries, most especially in Nigeria. For instance, in Nigeria some of the BIM studies were specific to each construction professional. For example, studies on BIM adoption and awareness in architectural firms (see Ibem *et al.*, 2018; Kori and Makarf, 2018; Kori *et al.*, 2019). BIM studies in facility management firms (see Ikediashi and Joseph,

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2016; Olapade and Ekemode, 2018) among others. In addition, for studies that examined BIM adoption, awareness, and implementation among Architecture, Engineering, and Construction (AEC) firms (see Olugboyega and Aina, 2016; Onungwa *et al*., 2017; Ganiyu *et al*., 2018; Olabode and Umeh, 2018). Few studies assessed BIM training gaps among construction professionals (see Oyewole and Dada, 2018). Few other studies examined BIM maturity level among AEC firms comprised architectural firms, facility management firms, quantity surveying firms, and structural engineering firms (see Babatunde *et al*., 2019). It can be seen that studies that investigate the important drivers to BIM adoption among construction professionals in the Nigerian construction industry through quantitative approach are limited. Therefore, investigating drivers to BIM adoption from different construction professionals will provide a richer and more practical knowledge of drivers to BIM adoption in Nigeria. It is against this backdrop that four different AEC firms comprised architectural firms, facility management firms, quantity surveying firms and structural engineering firms that already adopted BIM for their practices are considered as respondents in this study.

Research methodology

The target population for this study comprised only the BIM adopters' AEC firms in Lagos, Nigeria. In capturing broad responses, four different AEC firms were selected. These include: architectural firms; facility management firms; quantity surveying firms; and structural engineering firms in the study area. The choice of the study area is adjudged appropriate to undertake a survey and obtain the required data (Babatunde, 2015). The study adopted a literature review, a pilot study, and a questionnaire survey as follows:

Literature review

An extensive literature review was conducted in this study. The outcome of the literature review revealed 23 drivers to BIM adoptions in the wider contexts. These BIM drivers were identified from significant literature (see Azhar *et al*., 2008; Sacks *et al*., 2009; Wong *et al*., 2009; Coates *et al*., 2010; Arayici *et al*., 2011; Azhar *et al*., 2011; Eastman *et al*., 2011; Eadie *et al*., 2013) among others. The identified BIM drivers were utilized to design a questionnaire survey.

Pilot study

The pilot study was undertaken for the purpose of identifying the BIM adopters' AEC firms in the study area. Earlier to this, the total lists of aforementioned four selected AEC firms were obtained from their respective professional bodies in the study area. The outcome of the pilot study produced a total of 79 AEC firms that already adopted BIM for their practices. These include 41 architectural firms; 2 facility management firms; 25 quantity surveying firms; and 11 structural engineering firms.

Questionnaire survey

In order to capture broad responses of the respondents from the identified 79 BIM adopters' AEC firms, a questionnaire survey was employed. Using questionnaire survey was supported by many earlier researchers (see Blaxter *et al*., 2006) among others. The questionnaire was divided into two sections. This includes section 'A', which comprised the demographic features of the respondents such as the firm's category, number of firm's employee, firm's major client, highest academic qualifications of the respondent, years of work experience, and position of the respondents in their respective firms. Section 'B' was designed in line with the identified 23 drivers to BIM adoption. The questions were asked on a 5-point Likert scale, where 5- Very high, 4- High, 3- Moderate, 2- low, 1- very low. A total of 79

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questionnaires were self-distributed, out of which 67 questionnaires were completed and considered suitable for the analysis.

Moreover, a reliability test, particularly Cronbach's alpha test using SPSS was conducted in this study. The Cronbach's alpha test is regarded as one of the most popular reliability statistics in use (Cronbach, 1951). This is affirmed by Kothari (2009) that Cronbach's alpha test is one of the frequently used and acknowledged reliability coefficients. Therefore, the questionnaire for this study was subjected to Cronbach's alpha test using SPSS, the result indicated the reliability coefficient value of Cronbach's alpha 0.974; thus, this value signified that the questionnaire, including the Likert scale used in this study was significantly reliable and indicated evidence of internal consistency. This was supported by several earlier researchers. For instance, George and Mary (2003) stated that Cronbach's alpha value of greater than 0.6 is considered acceptable. Pallant (2007) asserted that the value for Cronbach's alpha should be higher than 0.7 for the scale to be reliable. In addition, obtained data were analysed using mean score, standard deviation, Kruskal-Wallis test, and factor analysis. For instance, the Kruskal-Wallis test was undertaken to determine whether there is a statistically significant difference in the ranking of the 23 identified drivers to BIM adoption among the respondents from four different BIM adopters' AEC firms. Using Kruskal-Wallis test was widely encouraged by earlier researchers when the samples are not less than three different groups with ordinal data (Fellows and Liu, 2008). Also, the factor analysis was carried out to identify a small number of factor categorizations (Pallant, 2010; Hair *et al*., 2010). Thus, the factor analysis was undertaken on the 23 identified drivers to determine the underpinning interactions or grouping that might exist between the identified drivers.

Results and discussion

Background information of the respondents

Table II indicates the background information of the respondents in terms of the firms category, number of firm's employee, firm's major client, highest academic qualifications of the respondents, years of work experience, and position of the respondents in their various firms. The distribution of the retrieved 67 questionnaires in relation to the firm's category shows that 32 respondents representing 52.2 percent are from architectural firms, 19 respondents representing 28.4 percent are from quantity surveying firms, 11 respondents representing 16.4 percent are from structural engineering firms, and 2 respondents representing 3.0 percent are from facility management firms. Regarding the number of employee in the firms, it can be seen from Table II that 53.7 percent of the firms have between 1 and 10 number of employee and 4.5 percent of the firms have more than 50 number of employee.

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

As indicated in Table II, the firm's major clients are the private individuals with 50.7 percent, followed by corporate organizations with 34.3 percent, and the least client is government with 15 percent. It is evident that, currently, BIM usage in Nigeria is being requested mostly by building owners and corporate organizations while the governments at all levels (i.e. federal, state and local) are not showing much interest in the implementation of BIM for the delivery of public projects. It is also evident from Table II, the current position of the respondents in their various firms. It shows that 49.3 percent of the respondents are managing directors /CEOs, followed by 38.8 percent are senior staff (see Table II for details). Based on the respondents' background information, it can be deduced that the respondents have

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adequate knowledge and experience on BIM adoption in AEC firms. Thus, it can be adjudged that the information provided by these respondents is reliable.

Ranking of the drivers to BIM adoption in AEC firms

Table III reveals the ranking of the 23 identified drivers to BIM adoptions from four different selected AEC firms. These include architectural firms, facility management firms, quantity surveying firms, and structural engineering firms. In the ranking, attributes with the same mean value are allotted ranks based on their standard deviation. In other words, an attribute with the lowest standard deviation is given a higher rank (Field, 2005). As indicated in Table III, the results of the ranking of the 23 identified drivers to BIM adoptions based on each AEC firm category are as follows:

Architectural firms: The top six ranked drivers to BIM adoption from respondents in architectural firms are: desire for innovation to remain competitive; improving the capacity to provide whole life value to client; time savings; streamlining design activities and improving design quality; cost savings and monitoring; and client/competitive pressure with their mean values of 4.41, 4.28, 4.27, 4.13, 4.10, and 4.07 respectively.

Facility management firms: The top six ranked drivers to BIM adoption from respondents in facility management firms include: desire for innovation to remain competitive; improving communication to operatives; facilitating facilities management activities; client/competitive pressure; streamlining design activities and improving design quality; and automation of schedule with their respective mean values of 5.00, 5.00, 5.00; 4.56, 4.56, and 4.56 respectively.

Quantity surveying firms: The top six ranked drivers to BIM adoption in quantity surveying firms are: desire for innovation to remain competitive; time savings; cost savings and monitoring; client/competitive pressure; streamlining design activities and improving design quality; and awareness of the technology among industry stakeholders with their mean values of 4.38, 4.31, 4.15, 4.15, 4.12, and4.09 respectively.

Structural engineering firms: The top six ranked drivers to BIM adoption in structural engineering firms include: time savings; accurate construction sequencing and clash detection; BIM software availability and affordability; awareness of the technology among industry stakeholders; improving the capacity to provide whole life value to client; and government pressure with their mean values of 4.46, 4.29, 4.29, 4.29, 4.26, and 4.26 respectively.

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

In addition, Table III displays the total ranking of the 23 identified drivers to BIM adoption in AEC firms. The total mean score values obtained from the aforementioned four selected AEC firms ranging from 3.67 to 4.45. These signify that the 23 identified drivers to BIM adoption are important. This is corroborated by Badu *et al.* (2012) stating that a factor is important if it has a mean score value of 3.5 or above, based on a five point Likert scale. Moreover, in the light of the aforementioned four selected AEC firms, the top six total ranked drivers to BIM adoptions include: desire for innovation to remain competitive; time savings; improving communication to operatives; accurate construction sequencing and clash detection; streamlining design activities and improving design quality; and client/competitive pressure with their respective total mean values of 4.45, 4.32, 4.26, 4.22, 4.21, and 4.19 respectively. These findings are slightly different from previous studies that found government pressure as one of the primary drivers to BIM adoption. For instance, Wong *et al*. (2009), BuildSmart

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(2012), and UK BIM Strategy Report (2012) reported that several governments of the developed countries such as the United Kingdom, United States and Australia among others have made the implementation of BIM compulsory on all public financed projects, which has led to a significant increase in BIM adoptions in those countries. This is affirmed by Lee *et al*. (2014) that BIM processes were made compulsory in the United States and United Kingdom government agencies in order to assist construction professional practices in the industry and to satisfy clients' needs and expectations. They further stated that since 2006, the general services administration in the United States had incorporated programme such as spatial arrangement of BIM as one of the least prerequisite for final approval of proposals. It is evident that the extent of BIM adoption is relatively low in countries where there are no government policies in place to encourage BIM adoption. It is quite unfortunate that there is no support from the government for BIM adoption in Nigeria, which is a true reflection of developing countries. Therefore, support from the government is un-negotiable to increase the BIM adoptions, particularly in developing countries.

In addition, Table III shows the results of the Kruskal-Wallis test that was undertaken to confirm if there is any statistically significant difference in the perceptions of the four selected AEC firms comprised architectural firms, facility management firms, quantity surveying firms and structural engineering firms in the ranking of the 23 identified drivers to BIM adoption. The results indicated that there is no statistically significant difference in the perceptions of the four selected AEC firms on the ranking of the 23 identified drivers to BIM adoption. This signifies that there is a strong agreement among the four groups of respondents on the ranking. It is evident that the respondents have a good understanding of the drivers to BIM adoptions. This is not surprising because the entire respondents have already adopted BIM for their practices and they are familiar with the Nigerian BIM environment.

Factor analysis on the drivers to BIM adoption in AEC firms

Factor analysis was carried out in this study, using principal factor extraction with varimax rotation on the 23 identified drivers to determine the underpinning interactions or grouping that might exist between the identified drivers. Prior to the carrying out of factor analysis, Kaiser-Mayer-Olkin (KMO) and Barlett's test of sphericity were conducted to confirm the data obtained are appropriate for factor analysis. For instance, Kaiser (1974) stated that a KMO value less than 0.60 is not appropriate for factor analysis.

>>>>>>>>>Insert Table IV>>>>>>>>>>

As shown in Table IV, the result of KMO value is 0.916, which implies that the data obtained is appropriate for factor analysis. Also, Bartlett's test of sphericity is 0.000, which denotes a strong correlation. This is supported by earlier studies that sphericity test should be less than 0.05 (Field, 2005; Pallant, 2010). It is obvious that the data obtained is appropriate for factor analysis given that the results of the KMO and sphericity are satisfactory. In order to further ascertain that the data obtained are suitable to undertake factor analysis, communalities on the identified 23 drivers to BIM adoption was conducted. This approach was supported by Field (2005) that communalities greater than 0.50 for all the factors to be investigated are suitable to conduct factor analysis. As indicated in Table V, all the identified 23 drivers to BIM adoption have the communalities greater than 0.50. This further confirmed the appropriateness of undertaking factor analysis in this study.

>>>>>>>>>Insert Table V>>>>>>>>>>

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Having confirmed the suitability of the data obtained for the factor analysis, the principal component analysis (PCA), eigenvalue, and the scree plot were utilized as decision criteria (see Pallant, 2010). This study adhered to the rule, as shown in Table VI; only two factors that have eigenvalue greater than 1.0 were retained. Further, Table VI contains the two factors that were retained with their eigenvalues of 2.614 and 13.768. The total variance of the first factor is 38.086% and 33.138% for the second factor. Also, the cumulative percentage of the total variance of the two factors amounts to 71.224% (see Table VI for details).

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

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

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

Table VII indicates the principal factor extraction with a varimax rotation undertaken on the 23 identified drivers to BIM adoption. The rotation matrix converged in 3 iterations. As indicated in Table VII, the extracted two principal factors have factor loadings ranging from 0.573 to 0.887, which signify that all the 23 identified variables are important and none of the variables needs to be eliminated (see Brown, 2009).

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

As shown in Table VII, the extracted two principal factors are interpreted as follows:
Factor 1: Cost and time savings, and improved communication
Factor 2: BIM awareness and government supports

Factor 1: Cost and time savings, and improved communication

This factor accounts for 38.086 percent (see Table VI) of the total variance of drivers to BIM adoption among AEC firms. The components of this factor includes: cost savings and monitoring; time savings; improving communication to operatives; accurate construction sequencing and clash detention; streamlining design activities and improving design quality; designing health and safety into construction process; and improving the capacity to provide whole life value to client among others (see Table VII for details). These components have high factor loadings of 0.887, 0.835, 0.817, 0.811, 0.810, 0.807, and 0.799 respectively. These findings are corroborated by Azhar *et al.* (2008) that BIM has the capability to reduce the time required as high as eighty percent to produce an estimate. Sacks *et al*. (2009) found that 4D BIM has the inherent ability to show electronically the virtual order of construction on screen and it is usually deployed by architects and planners to relate the order of operations that workmen are expected to carry out on site. Eadie *et al.* (2013) affirmed that, with the emergence of BIM, the project participants such as the building owner, project manager, contractor and designers (architects and engineers) can hold a meeting online at an agreed time to deliberate changes in the design and the cost can be modified instantly. It is evident that cost and time savings, and improved communication are one of the core drivers to BIM adoption among AEC firms. It is on this premise that this study recommends that AEC firms should show evidences of previous projects delivered using BIM for clients to have a holistic perception of BIM benefits, which will inevitably contribute positively to BIM adoption among AEC firms and construction industry at large.

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Factor 2: BIM awareness and government supports

This factor amounts to 33.138 percent (see Table VI) of the total variance of drivers to BIM adoption among AEC firms. The components of this factor are: awareness of the BIM among industry stakeholders; government support through legislations; collaborative procurement methods; BIM software availability and affordability; clients interest in the use of BIM in their projects; cultural change among industry stakeholders; enabling environment; cooperation and commitment of professional bodies to BIM implementation; and availability of trained professionals to handle the tools. These components have high factor loadings of 0.865, 0.850, 0.849, 0.842, 0.838, 0.827, 0.745, 0.744, and 0.632 respectively (see Table VII for details). Thus, in the absence of both BIM awareness among industry stakeholders and adequate government supports through legislations among others, BIM adoption among AEC firms may be negatively affected. These study findings confirmed the assertion of Alufohai (2012) that the extent of BIM implementation is relatively low in countries where there are no government policies in place to encourage BIM adoption. Currently, there is no support from the government at all levels (i.e. local, state, and federal) for BIM adoption in Nigeria, which is a true reflection of developing countries in general. Therefore, support from the government is un-negotiable to increase BIM adoptions in developing countries. Against this backdrop, this study recommends massive awareness of BIM by professional bodies, government agencies, and non-governmental organizations. Similarly, appropriate government policies that support BIM adoption should be in place. For example, governments in developing countries should encourage the adoption of BIM by making the implementation of BIM mandatory in all projects, and provision of adequate funds for training and procurement of BIM software and hardware, and provision of funds for the establishment of BIM-oriented building design standards.

Conclusion

This study provided empirical investigation of the drivers to BIM adoptions in AEC firms. In the light of the findings from four different selected AEC firms, which comprised architectural firms, facility management firms, quantity surveying firms and structural engineering firms that already adopted BIM for their practices. The study identified 23 drivers to BIM adoptions in AEC firms. The analysis of the total ranking of the 23 identified drivers from the aforementioned four selected AEC firms indicated the mean score values ranging from 3.67 to 4.45. These signified that the 23 identified drivers to BIM adoption are important. Moreover, in the light of the aforementioned four selected AEC firms, the top six total ranked drivers to BIM adoptions include: desire for innovation to remain competitive; time savings; improving communication to operatives; accurate construction sequencing and clash detection; streamlining design activities and improving design quality; and client/competitive pressure. These study findings are slightly different from previous studies that found government pressure as one of the primary drivers to BIM adoption. It can be deduced from these study findings that there are no government policies in place to encourage BIM adoption in Nigeria, which is a true reflection of developing countries in general. This is confirmed with the selected AEC firms' major clients, which revealed that private individuals with 50.7 percent, followed by corporate organizations with 34.3 percent, and the least client are government with 15 percent. It is evident that, currently, BIM usage in Nigeria is being requested mostly by building owners and corporate organizations while the governments at all levels (i.e. federal, state and local) are not showing much interest in the implementation of BIM for the delivery of public projects.

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Furthermore, the results of the Kruskal-Wallis test indicated that there is no statistically significant difference in the perceptions of the four selected AEC firms on the ranking of the 23 identified drivers to BIM adoption. This signified that there is a strong agreement among the four groups of respondents on the ranking. This could be attributed to the fact that the entire respondents have already adopted BIM for their practices, and they are familiar with the Nigerian BIM environment. Similarly, the findings from factor analysis grouped the identified drivers into two major factors to include: cost and time savings, and improved communication; and BIM awareness and government supports. As it showed in this study that cost and time savings and improved communication is one of the core drivers to BIM adoption among AEC firms. It is on this premise that this study recommends that AEC firms should show evidences of previous projects delivered using BIM for clients to have a holistic perception of BIM benefits, which will inevitably contribute positively to BIM adoption among AEC firms and construction industry at large. Also, BIM awareness and government supports as found in this study are important drivers to BIM adoption among AEC firms. Therefore, this study further recommends massive awareness of BIM by professional bodies, government agencies, and non-governmental organizations. Similarly, appropriate government policies that support BIM adoption should be in place in developing countries. These study findings provide important insights for policy makers and construction stakeholders, which would inform their decisions to make some policy recommendations capable of positively influencing the full BIM adoptions in AEC firms and construction industry at large.

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List of Tables

Table I: Identified drivers to BIM adoption in the construction industry

Code	BIM Drivers	Reference
D01	Government pressure	Arayici *et al.*, 2011; Efficiency and Reform Group, 2011;BuildSmart, 2012; Fitzpatrick, 2012; Eadie *et al.*, 2013
D02	Client/competitive pressure	Coates *et al.*, 2010; Liu *et al.*, 2010; Lu and Li, 2011; Eadie *et al.*, 2013
D03	Desire for innovation to remain competitive	Moore, 2003; Ruikar *et al*., 2005; Li *et al*.,2008; TRADA, 2012
D04	Improving the capacity to provide whole life value to client	Wolstenholme *et al*., 2009; Grilo and Jardim-Goncalves, 2010; Azhar*et al*., 2011; Deutsch, 2011; Barlish and Sullivan, 2012; Eadie *et al.*, 2013
D05	Streamlining design activities and improving design quality	Azhar *et al*., 2008; Deutsh, 2011; Eastman *et al.*, 2011; Eadie *et al.*,2013
D06	Designing health and safety into the construction process	Kiviniemi *et al.*, 2011; Eadie *et al.*,2013
D07	Improving communication to operatives	Sacks *et al*., 2009; Tutt *et al.*, 2011; Eadie *et al.*,2013
D08	Cost savings and monitoring	Azhar *et al.*,2008; Dickinson, 2010; Deutsch, 2011; BIMhub, 2012; Crotty, 2012; Barlish *et al.*,2012; Eadie *et al.*,2013
D09	Time savings	Azhar *et al*.,2008; Eastman *et al.*, 2011; BIMhub, 2012; Eadie *et al.*,2013
D10	Automation of schedule	Edum-Fotwe and McCaffer, 2000; Harris and McCaffer, 2006; Azhar, 2011
D11	Accurate construction sequencing and clash detection	Azhar *et al*.,2008; Leite *et al*., 2009; Azhar, 2011; Efficiency and Reform Group, 2011; Deutch, 2011; Eastman *et al.*,2011; BIMhub, 2012
D12	Facilitating increased pre-fabrication	Olofsson and Eastman, 2008; Eastman *et al.*,2011; Nawari, 2012; Eadie *et al.*,2013
D13	Facilitating facilities management activities	Zhang *et al*., 2009; Lewis *et al.*, 2010; Crotty, 2012
D14	Improving built output quality	Bazjanac, 2005; Dundas and Wilson, 2009; Samuelson and Björk, 2010
D15	Availability of trained professionals to handle the tools	Macdonald, 2012; Kiani *et al.*, 2015; Saleh, 2015; Badrinath *et al.*, 2016
D16	BIM software availability and affordability	Oladapo, 2007; Macdonald, 2012; Eadie *et al.*,2013
D17	Enabling environment	Oladapo, 2007; Takim *et al.*, 2013
D18	Clients' interest in the use of BIM in their projects	Liu *et al.*, 2010; BCIS, 2011; Lee *et al.*, 2012; Eadie *et al.*, 2013; Takim *et al.*, 2013; Lee and Yu, 2013; Saleh, 2015
D19	Awareness of the technology among industry stakeholders	Oladapo, 2007; Zikic, 2009; Newton and Chileshe, 2012; Hardi and pittard, 2015; Saleh, 2015
D20	Cooperation and commitment of professional bodies to its Implementation	Oladapo, 2007; Becerik-Gerber *et al.*, 2011
D21	Cultural change among industry stakeholders	Young *et al.*, 2008; Saxon, 2013; Kiani *et al.*, 2015; Saleh, 2015
D22	Government support through legislation	BCIS, 2011; Efficiency and Reform Group, 2011; buildingSMART, 2012; Eadie *et al.*, 2013; Zuhairi *et al.*, 2014; Kiani *et al.*, 2015
D23	Collaborative Procurement methods	Sinclair, 2012; Kuiper and Holzer, 2013

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Table II: Background information of the respondents

Characteristics of the respondent	Frequency	Percentage
Category of firms		
Architectural firm	35	52.2
Facility management firm	2	3.0
Quantity surveying firm	19	28.4
Structural engineering firm	11	16.4
Total	**67**	**100.0**
Number of firms' employee		
1 to 10	36	53.7
11 to 20	14	20.9
21 to 49	14	20.9
Above 50	3	4.5
Total	**67**	**100.0**
Firms' major client		
Private individuals	34	50.7
Corporate organizations	23	34.3
Government	10	14.9
Total	**67**	**100.0**
Highest academic qualifications		
MSc.	47	70.1
BSc/B.Tech	13	19.4
HND	5	7.5
ND	1	1.5
PhD	1	1.5
Total	**67**	**100.0**
Years of work experience		
1-5 years	7	10.4
6-10 years	14	20.9
11-15 years	14	20.9
16-20 years	16	23.9
21-25 years	4	6.0
26-30 years	12	17.9
Total	**67**	**100.0**
Position of the respondents		
Junior staff	6	9.0
Managing director /CEO	33	49.3
Senior staff	26	38.8
Technical staff	2	3.0
Total	**67**	**100.0**

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Table III: Ranking of the drivers to BIM adoption in AEC firms

BIM drivers	Architectural firms			Facility management firms			Quantity surveying firms			Structural engineering firms			Total Mean	Total Rank	Kruskal-Wallis Sig
	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank			
D01. Government pressure	3.40	1.18	23	4.00	0.00	17	3.94	1.15	14	4.26	0.91	6	3.90	19	0.054
D02.Client/competitive pressure	4.07	0.93	6	4.56	0.70	4	4.15	0.92	4	4.00	0.79	15	4.19	6	0.771
D03. Desire for innovation to remain competitive	4.41	0.85	1	5.00	0.00	1	4.38	0.82	1	4.02	0.70	13	4.45	1	0.342
D04. Improving the capacity to provide whole life value to client	4.28	0.99	2	4.00	0.01	18	4.12	0.70	5	4.26	0.60	5	4.16	7	0.942
D05. Streamlining design activities and improving design quality	4.13	0.98	4	4.56	0.71	5	4.02	0.92	9	4.14	0.76	7	4.21	5	0.762
D06. Designing health and safety into the construction process	3.92	0.98	12	4.25	1.37	11	3.81	0.97	21	4.14	0.76	8	4.03	15	0.631
D07. Improving communication to operatives	4.07	1.03	7	5.00	0.00	2	3.93	0.82	15	4.02	0.70	14	4.26	3	0.312
D08. Cost savings and monitoring	4.10	0.90	5	4.00	0.03	19	4.15	0.85	3	4.09	0.63	9	4.09	12	0.970
D09. Time savings	4.27	0.92	3	4.25	1.39	12	4.31	0.85	2	4.46	0.64	1	4.32	2	0.862
D10. Automation of schedule	4.05	1.02	9	4.56	0.73	6	3.91	0.81	16	4.07	0.73	12	4.15	8	0.681
D11. Accurate construction sequencing and clash detection	4.06	0.88	8	4.56	0.78	7	3.96	0.88	12	4.29	0.82	2	4.22	4	0.521
D12. Facilitating increased pre-fabrication	3.90	0.92	13	4.56	0.79	8	3.82	0.88	20	3.93	0.85	17	4.05	14	0.619
D13. Facilitating facilities management activities	3.76	0.88	18	5.00	0.00	3	3.74	0.85	22	4.07	1.10	11	4.14	9	0.220
D14. Improving built output quality	3.87	0.92	14	4.56	0.80	9	3.96	0.88	13	3.85	0.89	19	4.06	13	0.607
D15. Availability of trained professionals to handle the tools	3.66	0.99	22	4.00	0.05	20	3.88	0.99	19	3.68	0.87	22	3.81	22	0.650
D16. BIM software availability and affordability	3.83	1.06	15	4.25	1.40	13	4.04	1.07	8	4.29	0.84	3	4.10	10	0.405
D17. Enabling environment	3.98	1.05	10	4.00	0.07	21	3.89	0.92	17	3.83	0.51	20	3.92	18	0.959
D18. Clients interest in the use of BIM in their projects	3.83	1.18	16	3.00	0.00	23	3.98	0.93	10	3.88	0.70	18	3.67	23	0.496
D19. Awareness of the technology among industry stakeholders	3.79	1.08	17	4.25	1.42	14	4.09	0.94	6	4.29	0.87	4	4.10	11	0.236
D20. Cooperation and commitment of professional bodies to its implementation	3.92	1.07	11	3.57	0.70	22	4.09	0.97	7	3.80	0.75	21	3.84	21	0.806
D21. Cultural change among industry stakeholders	3.68	1.12	21	4.56	0.82	10	3.60	0.77	23	4.00	0.99	16	3.96	17	0.329
D22. Government support through legislation	3.71	1.27	20	4.25	1.45	15	3.98	1.12	11	4.07	0.94	10	4.00	16	0.368
D23. Collaborative Procurement methods	3.73	1.10	19	4.25	1.49	16	3.89	0.92	18	3.56	0.87	23	3.86	20	0.638

Significant at 5%

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Table IV: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.916
Bartlett's Test of Sphericity	Approx. Chi-Square	1896.805
	df	253
	Sig.	0.000

Table V: Communalities

	Initial	Extraction
Government pressure	1.000	0.770
Client/competitive pressure	1.000	0.548
Desire for innovation to remain competitive	1.000	0.634
Improving the capacity to provide whole life value to client	1.000	0.743
Streamlining design activities and improving design quality	1.000	0.759
Designing health and safety into the construction process	1.000	0.701
Improving communication to operatives	1.000	0.703
Cost savings and monitoring	1.000	0.808
Time savings	1.000	0.809
Automation of schedule/register generation	1.000	0.759
Accurate Construction Sequencing and Clash Detection	1.000	0.736
Facilitating increased pre-fabrication	1.000	0.725
Facilitating facilities management activities	1.000	0.697
Improving built output quality	1.000	0.569
Availability of trained professionals to handle the tools	1.000	0.633
BIM software availability and affordability	1.000	0.816
Enabling environment	1.000	0.750
Clients interest in the use of BIM in their projects	1.000	0.761
Awareness of the technology among industry stakeholders	1.000	0.828
Cooperation and commitment of professional bodies to its implementation	1.000	0.695
Cultural change among industry stakeholders	1.000	0.777
Government support through legislation	1.000	0.741
Collaborative Procurement methods	1.000	0.819

Note: Extraction Method: Principal Component Analysis.

Table VI: Total variance explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	13.768	59.859	59.859	13.768	59.859	59.859	8.760	38.086	38.086
2	2.614	11.365	71.224	2.614	11.365	71.224	7.622	33.138	71.224
3	0.928	4.036	75.260						
4	0.833	3.622	78.881						
5	0.702	3.052	81.933						
6	0.590	2.567	84.500						
7	0.483	2.098	86.598						
8	0.387	1.685	88.283						
9	0.378	1.645	89.928						
10	0.306	1.329	91.257						
11	0.294	1.280	92.537						
12	0.250	1.088	93.625						
13	0.226	0.983	94.608						
14	0.214	0.932	95.541						
15	0.192	0.834	96.374						
16	0.146	0.636	97.011						
17	0.138	0.602	97.612						
18	0.131	0.568	98.181						
19	0.115	0.499	98.680						
20	0.100	0.435	99.115						
21	0.092	0.401	99.516						
22	0.069	0.300	99.815						
23	0.043	0.185	100.000						

Note: Extraction Method: Principal Component Analysis

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Table VII: Rotated component matrix[a]

	Component	
	1	2
8. Cost savings and monitoring	0.887	
9. Time savings	0.835	
7. Improving communication to operatives	0.817	
11. Accurate construction sequencing and clash detection	0.811	
5.Streamlining design activities and improving design quality	0.810	
6. Designing health and safety into construction process	0.807	
4. Improving the capacity to provide whole life value to client	0.799	
10. Automation of schedule/register generation	0.787	
12. Facilitating increased pre-fabrication	0.785	
3. Desire for innovation to remain competitive	0.716	
13. Facilitating facilities management activities	0.703	
2. Client/competitive pressure	0.608	
14. Improving built output quality	0.574	
1.Government pressure	0.573	
19. Awareness of the BIM among industry stakeholders		0.865
22. Government support through legislation		0.850
23. Collaborative procurement methods		0.849
16. BIM Software availability and affordability		0.842
18. Clients interest in the use of BIM on their projects		0.838
21. Cultural change among industry stakeholders		0.827
17. Enabling environment		0.745
20. Cooperation and commitment of professional bodies to its implementation		0.744
15. Availability of trained professionals to handle the tools		0.632

Note: Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization
a. Rotation converged in 3 iterations

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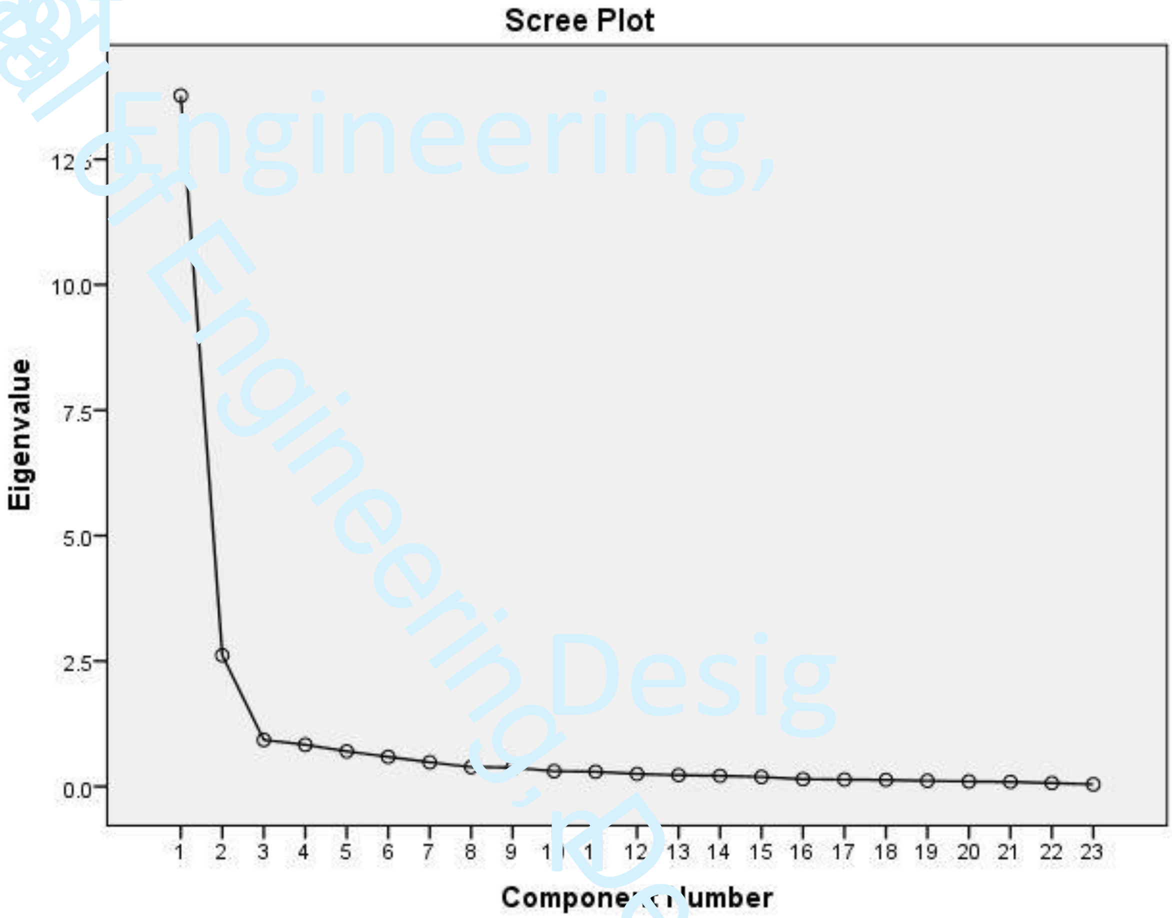

Figure I: The scree plot showing extracted factors on the 23 identified drivers to BIM adoption among AEC firms

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