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An investigation into BIM uptake among contracting firms: an empirical study in Nigeria

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Abstract

Purpose – Building Information Modeling (BIM) is vital in the performance improvement of contracting firms. Thus, there is a need to stimulate its implementation in the construction sector with a view to meeting the competitive demands of the industry. However, there have been very few studies on BIM implementation among contracting firms in Nigeria. Hence, this study examines the current BIM uptake among Nigerian contracting firms, assesses the barriers to BIM implementation, and examines ways of improving BIM implementation within these contracting firms.

Design/methodology/approach – A questionnaire survey was conducted on contracting firms (comprising small, medium and large sized firms) in Lagos, Nigeria. The obtained data were analyzed using both descriptive and inferential statistics. These included percentage, mean score, standard deviation, the Kruskal-Wallis test and factor analysis.

Findings – The study revealed the current state of BIM implementation among contracting firms in Nigeria in terms of their knowledge of BIM, their usage of BIM as well as the BIM software adopted. Furthermore, the study identified 25 barriers to BIM implementation in contracting firms and identified 15 ways to improve BIM implementation in contracting firms. The relative importance of both the identified barriers and the ways for improving BIM implementation was gauged among contracting firms comprising small, medium and large sized firms. The result of the Kruskal-Wallis test revealed that, except for two (out of 25) identified barriers, and one (out of 15) identified ways of improving BIM implementation in contracting firms, there is no significant statistical difference in the perceptions of the three respondents' groups. The result of the factor analysis categorized the identified 25 barriers into seven main factors.

Practical implications – The study provides empirical evidence on the barriers to BIM implementation and the ways of improving its implementation among contracting firms; thereby providing a better insight of the Nigerian construction industry's BIM environment.

Originality/value – The study's findings can positively inform the decisions of construction stakeholders to formulate strategies capable of improving BIM implementation in the construction industry at large.

Keywords: BIM, barriers, construction companies, construction industry, developing countries

Paper type: Research paper

Introduction

One of the largest industries known worldwide is the construction industry although, in terms of productivity, efficiency, quality and sustainability, it is still behind other industries. This is due to its inefficiency and a lack of production which have been ascribed to its composite nature of project delivery. Hence, it has faced many criticisms from across the world (Akintoye and Fitzgerald, 2000). An increase in production output can be linked to a better usage of information technologies (this factor can be ascribed to other industries as well as to the construction industry). The major source of concern for stakeholders in the construction industry is the need to increase productivity and returns on investments (ROIs) in construction project delivery. Additionally, there is poor communication between project stakeholders leading to a lack of efficiency and reduced output as a result of disintegration in the construction industry (Latham, 1994). Increased wastage, rework, time overruns, cost overruns and adversarial positions are common occurrence because of perceived or actual changes (resulting from the reduction in effectiveness) being nurtured by various factors in construction projects than for any other reason. Some other examples of problems within the construction industry are contractors who are aggressive threatening to slow down work or stop the work if they are not paid, clients claiming and insisting that extra conditions have been left out, expanded projects, and extra features which have to be covered by the original non-fluctuating bid price (Berger, 2008).

Increased productivity and coordination in the construction industry is imperative because the industry is becoming more complex and is taking longer to construct (Infocomm, 2011). The act of using computer-generated models to improve design and planning (among other aspects) in construction projects is known as BIM. Generally, all over the world, the uptake of BIM implementation in the construction industry is occurring rapidly. The design process as well as the construction of buildings is changing (Hassan and Yolle, 2009). Depending on agreement among the clients, manufacturers, contractors, architects, and engineers (including other consultants), BIM is seen as a new approach to design. However, Marderson *et al*. (2015) claimed that the implementation of BIM in the construction industry is still in its early stages despite its numerous advantages. This is affirmed by Cao *et al*. (2016) who stated that a large percentage of contracting firms are still in the early adoption stage. For instance, Forsythe (2014) argued that, in small firms, the low uptake of BIM implementation has been an issue. Yet there are a lot of studies focused on BIM implementation within large sized and large-scale projects (Forsythe, 2014; Rodgers *et al*., 2015). Additionally, challenges to BIM implementation in small and medium sized firms have received insufficient recognition in existing studies (Poirier et al., 2015). The fact that small and medium sized firms will continue to dominate the construction industry landscape far into the future makes studies on BIM within contracting companies of the utmost importance (Shelton *et al*., 2016).

In Nigeria, various studies on BIM have focused on awareness of BIM, adoption, benefits and challenges, both from the industry and academic perspectives (Ibironke *et al*., 2011; Abubakar *et al*., 2014; Marcus *et al*., 2015; Ugochukwu *et al*., 2015; Hamma-adama *et al*., 2017; Onungwa *et al*., 2017; Babatunde *et al*., 2018; Babatunde and Ekundayo, 2019). A few of these studies have examined the barriers to BIM implementation (see Abubakar *et al*., 2014; Babatunde and Ekundayo, 2019). For instance, Abubakar et al. (2014) evaluated the perceptions of contractors on the factors influencing BIM in Nigeria. This study failed to evaluate the BIM barriers from the perceptions of each category of contracting firms (i.e. from small, medium and large sized firms). Babatunde and Ekundayo (2019) paid attention to the barriers to the incorporation of BIM into quantity surveying education from both academia and students' perspectives; hence the study (Babatunde and Ekundayo, 2019) did not examine the phenomenon from industry stakeholders' perspectives. Babatunde *et al*. (2019) went further to assess and compare the current levels of BIM maturity among AEC firms such as architectural, structural engineering, quantity surveying and facility management firms in Nigeria. However, this study only investigated the factors responsible for the different current BIM maturity levels exhibited by the identified AEC firms. Therefore, there is a need to critically investigate the current uptake of

BIM implementation in the Nigerian construction industry. It against this backdrop that the following objectives are derived:

- To investigate the current uptake of BIM implementation among Nigerian contracting companies (comprising small, medium and large sized firms);
- To identify and examine the barriers to BIM implementation among the different Nigerian contracting company categories (i.e. among small, medium and large sized firms; and
- To investigate the ways of improving BIM implementation among the different Nigerian contracting company categories (i.e. among small, medium and large sized firms).

It is believed this study will provide a worthwhile insight into the Nigerian construction industry's BIM environment. The study findings should further inform the decisions of the construction stakeholders to make some policy recommendations capable of positively influencing full BIM implementation in the industry.

Literature review

BIM implementation and the construction industry

Fragmentation in the activities of the construction industry has been fuelled by both poor documentation and information management. The industry is characterized by low productivity and inefficiency as well as poor performance. For instance, Olatunji *et al*. (2010) argued that design errors and estimate deficiencies are some of the problems which reduce the flow of information throughout project life cycles. Several earlier studies have alluded to the need for an improved performance in the industry to deliver value for money and to effectively meet the needs of its clients. Against this backdrop, BIM is considered as the solution to some of these problems, even if not all, because it serves as a platform for consistent communication and collaboration among all construction stakeholders as well as having the capacity of bringing cleaniness into the design and construction processes leading to an improved general performance of the industry (Abubakar *et al*., 2014). BIM implementation has a lot of potential for improving the design, construction, and maintenance of buildings. This is corroborated by Eastman *et al*. (2011) who stated that the quality, efficiency and output of construction projects can be potentially increased by BIM. Furthermore, BIM gives a more comprehensive and accessible exposition of a building as well as giving more detailed and updated information. Several benefits are associated with BIM implementation on a construction project. These include, amongst others, the ability to ensure early joint decision-making, the clarity of better design, a stronger connection between the design and cost, virtual configurations and designs, better vision projections and simulations of best asset performance, reduced waste, merely minor errors in documentation, lower cost, better construction results, better predictions on performance outcomes, improved knowledge of the whole lifecycle, and data sharing among all the professionals from cradle to grave (Suermann, 2009; Azhar, 2011; Barlish and Sullivan, 2012; Hong *et al*., 2019). However, there are several socio-technical barriers which continually reduce the construction industry's ability to fully utilize the potentials of BIM despite its perceived benefits (Arayici, 2012; Bernstein and Pittman, 2014; Olawumi *et al*., 2017; Chan *et al*., 2019). In the Australian construction industry, Rodgers et al. (2015) claimed that about 45% of contracting firms have been using BIM in the South Australia compared to previous studies conducted around 2010 (see Gerrard *et al*., 2010). The rate at which BIM has been utilised in the Australian construction industry indicates the likely successful steps that the Australian contracting firms have taken to keep up with BIM trend. However, using integrated BIM with a satisfied level of collaboration from among stakeholders has remained a distant objective for the Australian contracting firms (Gerrard *et al*., 2010; Forsythe, 2014).

In Nigeria, however, the adoption of BIM is yet to be fully accepted in order to increase or enhance construction project delivery (Ibrahim and Bishir, 2012). The construction industry in Nigeria is slow to change and widely conservative. For example, building project delivery methods and traditional procurement have remained the same for some decades. There has been a very slow move towards BIM adoption in Nigeria, both within the public (client side) and private sectors and among various construction professionals such as quantity surveyors, engineers and architects among others. A few architects have adopted BIM merely in order to enhance the visual quality of their presentations. And this is unfortunate because of its extraordinary potential to improve outputs and cost savings as well as curb corruption (Alufohai, 2012). Therefore, there is a need to stimulate its implementation in the construction industry, particularly among contracting firms, in order to meet the competitive demands in the industry. BIM can play a crucial role in performance improvement in contracting firms, but little has been done about its implementation among the contracting categories, particularly within developing countries.

Overview of BIM implementation in the Nigerian construction industry

The Nigerian construction industry is bedevilled by myriads of challenges such as cost overrun, time overrun, project abandonment, disputes, inefficiency and poor service delivery (Kolo and Ibrahim, 2010; Ameh, 2011; Ogwueleka, 2011; Babatunde *et al*., 2019). Therefore, there is a need for improved performance and efficiency in the Nigerian construction industry to deliver value for money and to effectively satisfy the needs of its clients. Hence, BIM is considered as the solution to some of these challenges, even if not all, because it serves as a platform for consistent communication and collaboration between all construction stakeholders as well as having the capacity of bringing cleaniness into the design and construction processes leading to an improved general performance of the construction industry in Nigeria (Abubakar *et al*., 2014). However, the extent of BIM adoption in Nigeria is best described as stagnant (Ibrahim and Bishir, 2012). For instance, Hamma-adama *et al*. (2017) stated that the current status of BIM uptake in Nigeria is predominantly by the usage of 2D and 3D. This is affirmed by Olugboyega and Aina (2018) who reported that both 2D and various variants of 3D BIM (such as 3D architectural model, 3D architectural and structural model and 3D architectural and building services model) are mostly used in Nigeria. Currently, BIM usage in Nigeria has been mostly requested by building owners and developers. The government at all levels (i.e. federal, state and local) is not showing much interest in the implementation of BIM for the delivery of public projects. This is contrary to the interest shown in BIM by governments in most developed countries. In the UK, for example, the government has made the usage of BIM compulsory on all public financed projects since 2016. Whilst in Australia and several European countries (such as the Netherlands, Norway, Spain, France and Germany among others) BIM has been increasingly used for many years because governments and several large public clients very often require the use of BIM in some or all their projects. It is on this premise that Alufohai (2012) asserted that the major driving force towards the higher utilization of BIM is governmental support. This assertion is also supported by Chan et al. (2019) in the case of Hong Kong.

Although, various studies have focused on the importance of BIM as a dependable instrument which can be used in the Nigerian construction industry, others have focused on the benefits of BIM in the Nigerian construction industry. For instance, Akerele and Etiene (2016) have assessed the level of BIM awareness and limitations within Nigeria. The authors found that the level of BIM awareness is generally low among professionals in the Nigerian construction industry. This lack of awareness on the use of BIM is the major factor contributing to its low level of implementation. Additionally, there is a lack of support from the government for its full adoption in the Nigerian construction industry. Abubakar *et al*. (2014) evaluated the perceptions of contractors on the factors affecting BIM adoption in Nigeria and found, among other factors, that there is social and consistent resistance to change, a high cost of BIM software and a lack of an enabling environment in the form of government policies and legislation regarding BIM adoption. In all these previous studies, the focus has largely been on the level of BIM awareness, on BIM implementation, and on the benefits of BIM adoption among construction professionals. Although these previous studies have been of great help to know more about the current situation regarding BIM in Nigeria none has holistically investigated the current uptake of BIM implementation among contracting companies, comprising small, medium and large sized firms, or examined the barriers to BIM implementation among contracting company categories in the Nigerian construction industry.

Barriers to BIM implementation in construction industry

Despite the increasing awareness and perceived benefits of BIM, only two countries to date have more than a 50 percent adoption rate with the UK recording more than 55 percent and the USA with more than a 75 percent adoption rate, according to Olawumi *et al*. (2017). Various viewpoints have been documented on most of the challenges that have contributed to the slow implementation of BIM in the construction industry (see Ghaffarianhoseini *et al*., 2017; Gerbov *et al*., 2018; Gamil, 2019; Georgiadou, 2019; Zhou *et al*., 2019 among others). These barriers can be classified into environmental, technological and organizational factors (Mahamadu, 2013). This categorization is consistent with a Technology, Organizational and Environmental (TOE) framework which has, in the past, been used in Information Technology (IT) studies in the categorization of factors of implementation (Tornatzky and Fleischer, 1990). Facilitating the ease of BIM implementation through software vendors, institutions of professionals, the market, and projects provided by government are mainly macro level facilitating conditions as well as all other issues are the environmental factors (Mahamadu, 2013; Sargent, 2012). All technical issues relating to the capabilities of BIM, including its characteristics, come under the technology factors. All the social stimuli of the technology adoption together with organizational elements which allude to internal organizational issues (i.e. the general form, raw materials, people and leadership) are the organizational factors (Davies and Hart, 2013; Mahamadu, 2013). Across the three elements of the construction industry, namely the supply chain, the organization and the project itself the major barriers that have been identified stem from the fact that the parties involved in the supply chain lack interest in BIM implementation. Additionally, there are negative mind sets regarding the huge effort and money that needs to be put in place for its implementation among the contracting firms. This implies that a lack of interest in accepting the risks that could accompany the return on interest (ROI) of BIM could be explained as the major barrier. This could be interpreted as the ROI received on investments in, and allocated resources to, BIM implementation could directly influence the level of BIM implementation undertaken by various decision makers (McGraw, 2014). Taking these risks by contracting firms which are still struggling for survival in the market can be said to be beyond an acceptable level. Naturally, contracting firms have a tendency to adopt previously-verified guaranteed ROI gained by reliable methods (Poirier et al., 2015a).

Within the organizational context/element factors such as inadequate knowledge, comfortability with current technologies, a lack of skill and expertise to adopt BIM, the cost of adoption, the high cost of training (among similar other factors on projects) can be ascribed to the lack of an organizational long term strategy or to the lack of an organizational structure within contracting firms (Poirier *et al*., 2015b). The efforts of policy makers and BIM advocates have to be focused on these two points (namely, the lack of an organizational long term strategy, and the lack of an organizational structure) in order to promote BIM implementation among contracting firms.

Azar (2012) stated that interoperability risks (i.e. between the different used programmes) are viewed as some of the crucial challenges in the adoption of BIM. When at the post contract stage of the project, this affects the arrangement of construction working drawings and restricts the use of BIM. However, even when each field works in a 3D environment, collaboration in Nigeria is still based on exchanging drawings in 2D (Khemlani, 2007). In Nigeria, the poor state of electricity and other infrastructure can be concluded as being an obstacle that affects the adoption of ICT in the Nigerian construction industry (Oladapo, 2007). Work in offices is affected by the constant lack of electricity and the lack of internet connectivity (Abubakir *et al*., 2014). While the adequate use of BIM requires full internet connection, the constant use of generators increases the cost of running offices because obtaining the BIM drawings requires internet connection. As a result of slow internet speeds, as well as issues with the supply of electricity, and because BIM systems require large files, it means that the administration, and conveying, of these records will not be easy to undertake in Nigeria (Abubakar *et al*., 2014). Despite these previous studies, Poirier *et al*. (2015a) argued that few studies have investigated the barriers to BIM implementation among small, medium and large sized firms.
Based on the foregoing, the identified barriers to BIM implementation in the construction industry have been summarized, and are presented in Table I as follows:

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

Similarly, the ways of improving BIM implementation in the construction industry that were identified by Kekana et al. (2015) and Ruya et al. (2018) have been adapted in this study. Since these studies were conducted in the South African and Nigerian construction industry respectively, hence the identified ways of improving BIM implementation were judged to be relevant in this study. These identified ways of improving BIM implementation were filtered to avoid duplication, and are presented in Table II.

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

Thus, this study empirically investigates the current uptake of BIM within the Nigerian small, medium and large contracting firms; examines the barriers to BIM implementation among contracting company categories in the Nigerian construction industry; and investigates the ways of improving BIM implementation among Nigerian contracting firm categories.

Research methodology

This study focused on BIM implementation within contracting companies comprising small, medium and large sized companies in Lagos, Nigeria. The choice of the study area was based on the premise that many construction companies are located in the area and thus this fact facilitated adequate data collection. In addition, a literature review was undertaken and the outcome revealed the 25 barriers to BIM implementation in the wider context (see Table I). Similarly, the review of the literature revealed the 15 ways of improving BIM implementation in the construction industry (see Table II). Therefore, both the identified barriers to BIM and the ways of improving BIM implementation were used to design a questionnaire survey. In order to capture the broad responses of the respondents from the different contracting firms' categories in the study area, a questionnaire survey was employed. Using a questionnaire survey is supported by many earlier researchers (see Blaxter *et al*., 2006). For instance, relevant previous studies on BIM have used a questionnaire survey. (For example, among others, Kekana *et al*. (2015) used a questionnaire survey when exploring BIM in the South Africa construction industry. Ruya *et al*. (2018) employed a questionnaire survey when assessing the challenges of BIM in the Nigerian construction industry. Olawumi and Chan (2019) used a questionnaire survey when developing a benchmark model for BIM implementation in developing countries). The data were obtained through a well-structured questionnaire distributed among contracting firms comprising small, medium and large sized firms in the study area. Among the sections of the questionnaire (for eliciting information) were the demographic profile of the respondents, the current state of BIM implementation among contracting firms, the BIM software in use by the respective firms' category, the barriers to BIM implementation among contracting categories, and the ways of improving BIM implementation among contracting categories.

The target population for this study was contracting firms comprising small, medium and large sized contracting firms in the study area. The total list of the aforementioned categories of contracting firms within the study area was extracted from the 5th Procurement Journal of December 2016. Thereafter, a random sampling technique was adopted for the selection of the required number of respondents from both the small and medium contracting firms, and the total enumeration was employed for the large size firms; this resulted in a total of 236 contracting firms of varying sizes selected as the sample size in this study. Hence, a total of 236 questionnaires were self-distributed to the contracting firms of varying sizes in the study area, out of which a total of 85 questionnaires (representing 36%) were completed and considered appropriate for the analysis. The response rate of 36% was above the 20-30% threshold considered to be adequate for questionnaire surveys in construction management studies (Akintoye, 2000; Akintoye and Fitzgerald, 2000; Dulaimi *et al*., 2003; Fellow and Liu, 2008). Therefore, the survey was adjudged to be free from non-respondent bias. The low response rate could be attributable to the tight schedule of the respondents and because they had also served as respondents to many other researchers in the study area. Despite the response rate, statistical analysis could still be conducted as the central limit theorem holds true with a sample size greater than 30 (Ling *et al*., 2004).

The data obtained were analyzed using frequency, percentage, mean score, standard deviation, the Kruskal-Wallis test, and factor analysis. For instance, the Kruskal-Wallis test was undertaken to ascertain if there was a statistically significant difference in the ranking of both the 25 identified barriers to BIM implementation and the 15 identified ways of improving BIM implementation among the contracting firms comprising small, medium and large sized firms. The use of the Kruskal-Wallis test has been 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 25 identified BIM barriers to determine the underlying interactions or groupings that might exist between the identified BIM barriers.

Results and discussion

Demographic profile of both the firms and respondents

Table III shows the background profile of the firms and the respondents in relation to the categories of the firm, the numbers of employees, the specialty of the firms, the years of the firms' establishment, the major clients of the firms, the professional background of the respondents in their respective firms, the position of the respondents in their firms, and the highest academic qualification of the respondents. As indicated in Table III, the categories of the firm show that the small firms represented 41.18 percent, the medium firms represented 27.06 percent and the large firms represented 31.76 percent. The specialty of the firms revealed that a higher percentage of the firms focused on building works (with 58.82 percent), followed by engineering services' works (with 18.82 percent), while 3.53 percent of the firms were undertaking specialist works and 16.7 percent of the firms were involved in all the aforementioned works. The question on the major clients of the firms revealed that the government is the major client (with 42.35 per cent), followed by individual/owner (with 34.12 percent) while private organizations are 14.42 percent. The academic qualifications of the respondents revealed that the highest percentage of respondents' academic qualifications was at the BSc level (Bachelor's degree) (with 36.47 percent) followed by MSc (Master's degree) (with 22.35 percent) while 11.76 percent of the respondents had obtained a HND (Higher National Diploma) (see Table III for details).

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

Current uptake of BIM implementation in the contracting firms

This section shows the current uptake of BIM implementation among contracting firms in terms of their knowledge of BIM, usage of BIM, the type of projects BIM is being used for, as well as the BIM software adopted for use. Table IV indicates the knowledge of BIM as given by the respondents. It shows that 89.41 percent of the respondents have heard about BIM, while 10.59 percent of the respondents have not heard about BIM at all. Similarly, the question regarding knowledge of BIM revealed that the highest percentage of respondents with BIM knowledge were those who work in firms using BIM (with 53.95 percent) followed by those who read research relating to BIM (with 21.05 percent), and 17.11 percent of the respondents were those who were training on the usage of BIM (see Table IV for details). Table IV further reveals that 65.88 percent of the respondent firms have used BIM in some of their firm's projects, while 34.12 percent of the firms have not used BIM in any of their firms' projects. The respondents' responses on how their firms use BIM show that 36.47 percent of the firms use BIM often, 23.53 percent of the firms always uses BIM, while 34.12 percent of the firms have never used BIM (see Table IV for details). In addition, the respondents' selection of the types of project they used BIM for shows that 23.22 percent use BIM for educational buildings, 35.71 percent for residential projects, while 7.14 percent use BIM for public projects (see Table IV for details).

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

Moreover, regarding the BIM software adopted for use among the contracting firms, Figure I indicates that AutoCAD Architecture has the highest percentage of usage (with 20 percent) followed by Revit Architecture and ArchiCAD (with 15 percent each), while both Vela Field BIM and Nemmetschek Scia are not used at all, hence they have zero percent of usage (see Figure I for more details).

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

Ranking of the barriers to BIM implementation among contracting firms

Table V shows the ranking of the 25 identified barriers to BIM implementation among the small, medium and large contracting firms. In the ranking, attributes with the same mean value are ranked based on their standard deviation. In other words, an attribute with the lowest standard deviation is given a higher rank (Field, 2005). As shown in Table V, the results of the ranking of the 25 identified barriers to BIM implementation based on each contracting firm category are as follows:

Small contracting firms: The top five ranked barriers to BIM implementation from respondents in the small contracting firms are: the cost of the hardware and BIM software; BIM experts' shortage; difficulty in managing sophisticated data; weak cooperation among different professions, and the cost of BIM training, with the mean values of 4.48, 4.46, 4.46, 4.45 and 4.43 respectively.

Medium sized contracting firms: The top five ranked barriers in the medium sized contracting firms include: weak education and training; the cost of BIM software and its updates; problems relating to interoperability; issues of power supply and weak internet connectivity, and not knowing where to start, with their respective mean values of 4.59; 4.58; 4.54; 4.54 and 4.54 respectively.

Large sized contracting firms: The top five ranked barriers to BIM implementation in the large sized contracting firms are: the cost of BIM training; the cost of BIM software and its updates; the cost of the hardware and BIM software; weak education and training, and not knowing where to start, with their mean values of 4.61, 4.55, 4.53, 4.50 and 4.48 respectively.

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

Table V further reveals the total mean score values for the 25 identified barriers to BIM implementation among the small, medium and large contracting firms ranging from 4.06 to 4.51 (see Table V). It can be deduced that all the respondents considered these identified 25 barriers important. This is corroborated by Badu *et al.* (2012) who stated that a factor is important if it has a mean score value of 3.5 or above, based on a five point Likert scale. Thus, the top five ranked barriers to BIM implementation in contracting firms are: the cost of the hardware and BIM software; not knowing where to start; the cost of BIM software and its updates; problems relating to interoperability, and the cost of BIM training, with their respective total mean values of 4.51, 4.47, 4.46, 4.42 and 4.41 respectively. These study findings are slightly different from previous studies that found fear of change as one of the barriers to BIM implementation. For instance, Hassan and Yolles (2009) stated that most contracting firms find it difficult to change because they feel comfortable with the previous software that they have been using even though other software may be more advanced. It was found in this study's findings that a lack of awareness, and knowledge on BIM, are no longer a major barrier to BIM implementation in contracting firms. Thus, the major barriers to BIM implementation have shifted to the cost-related barriers among the contracting firms. This study, therefore, advocates that governments should encourage BIM implementation in the construction industry by making provision for adequate funds for training and the procurement of BIM software and hardware, including BIM upgrading, particularly in developing countries. In addition, the result of the Kruskal-Wallis test undertaken at a significance level of 5 percent showed that, except for 2 (out of 25) identified barriers, there are no significant statistical differences in the perceptions of the respondents in the three categories of contracting firms (comprising small, medium and large sized contracting firms). This shows that there is a common understanding of the barriers to BIM implementation among the contracting firms in Nigeria.

Ranking of the ways of improving BIM implementation among contracting firms

Table VI indicates the ranking of the 15 identified ways of improving BIM implementation among contracting firms. Based on contracting firms' category, the findings are as follows:

Small contracting firms: The top five ranked ways of improving BIM implementation from the respondents in small contracting firms are: feasible ways of migrating from common practice into BIM; educating government departments on 'model based' deliverables and their benefits; BIM integration into education curricula; increase in the availability of BIM technology, and development of BIM forms of contract for stakeholders, with their mean values of 4.70, 4.68, 4.65, 4.65 and 4.60 respectively.

Medium sized contracting firms: The top five ranked ways of improving BIM implementation in medium sized contracting firms include: development of BIM intellectual property; BIM forms of contract development for stakeholders; improvement on BIM interoperability; organized BIM workshops for stakeholders, and government enforcement of BIM usage, with their respective mean values of 4.66, 4.66, 4.64, 4.63 and 4.61 respectively.

Large sized contracting firms: The top five ranked ways of improving BIM implementation in large sized contracting firms are: government enforcement of BIM usage; BIM skills' development programmes; educating government departments on 'model based' deliverables and their benefits; BIM integration into education curricula, and BIM forms of contract with insurance, with their respective mean values of 4.69, 4.67, 4.61, 4.57 and 4.52 respectively.

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

As further revealed in Table VI, the total ranking of the 15 identified ways of improving BIM implementation in contracting firms showed the total mean values ranging from 4.30 to 4.63; this signified that all the 15 identified ways of improving BIM implementation are considered important. In addition, the top five ranked ways of improving BIM implementation in contracting firms are: government enforcement of BIM usage; BIM integration into education curricula; BIM skills' development programmes; educating government departments on 'model based' deliverables and their benefits, and development of BIM warranty requirements, with their respective mean values of 4.63, 4.61, 4.60, 4.56 and 4.54 respectively. These findings affirm the existing literature. For instance, the UK BIM Strategy Report (2012) and BuildSmart (2012) reported that several governments in developed countries such as the United Kingdom, United States of America and Australia have mandated the usage of BIM on public-financed projects, which has led those countries to be the most recognized and leading countries in BIM implementation. Similarly, Han and Bedrick (2015) asserted that BIM implementation would suffer without its integration into education modules in higher education. Therefore, an emphasis should be placed on the need to incorporate BIM education into engineering, architecture, and quantity surveying programmes as well as within other construction related disciplines. Furthermore, the results of the Kruskal-Wallis test revealed that except for 1 (out of 15) identified ways of improving BIM implementation in contracting firms, there is no significant statistical difference in the perceptions of the three respondents' groups comprising small, medium and large contracting firms.

Factor analysis on barriers to implementation of BIM in contracting firms

Factor analysis was undertaken on the 25 identified barriers to BIM implementation among the contracting firms. After the data were obtained they were subjected to Kaiser-Meyer-Olkin (KMO) test and Bartlett's test of Sphericity. The results of the KMO value of 0.895 and Bartlett's test of Sphericity value of 0.000 imply that the data obtained was appropriate to undertake factor analysis (see Pallant, 2010). In addition, Field (2005) asserted that the communalities of the entire components greater than 0.50 are appropriate to conduct factor analysis. In this regard, communalities were conducted in this study. As depicted in Table VII, all the identified 25 barriers to BIM implementation among contracting firms in this study achieved communalities greater than 0.50 (see Table VII).

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

Regarding the sample size, several suggestions have been made on the most suitable sample size for factor analysis. For instance, Hinton et al. (2004) and Pallant (2007) recommended a minimum ratio of two responses for every item or variable. Hair *et al.* (2010) claimed that the sample size should be greater than 50 for factor analysis to be conducted. Thus, with the number of survey respondents being 85, this study is adjudged suitable for factor analysis. In this regard, the requirements for the KMO test, Barlett's test of Sphericity, communalities, and the sample size are all met. This justified that factor analysis is appropriate for this study. Thereafter, as shown in Table VIII, principal component analysis (PCA) and eigenvalue were used as decision criteria (see Pallant, 2010). For example, variables with an eigenvalue greater than 1.0 were considered in this study.

>>>>>>>>**Insert Table VIII**>>>>>>>>>

Table VIII indicates the PCA results conducted on the 25 identified barriers to BIM implementation in contracting firms. As shown in Table VIII, the first seven components had eigenvalues greater than 1.0; thereby the seven factors were considered for the analysis. The total cumulative percentage of the extracted seven factors amounts to 65.517 percent.

In addition, Table IX reveals the principal factor extraction carried out on the 25 identified barriers to BIM implementation. As shown in Table IX, the seven extracted factors have the factor loadings between 0.496 and 0.826; hence all the variables are important in the analysis (see Kline, 2002; Brown, 2009).

>>>>>>>>**Insert Table IX**>>>>>>>>>

Thus, the seven extracted factors are named as follows:

Factor 1: Absence of BIM specialists, standards and protocols
Factor 2: Client related issues and high initial BIM outlay
Factor 3: Weak BIM skills and resistance to change
Factor 4: Cooperation issues with managing complicated data
Factor 5: Lack of BIM tangible benefits and intellectual property related issues
Factor 6: Non-governmental support and BIM working environment related issues
Factor 7: Interoperability issues

Factor 1: Absence of BIM specialists, standards and protocols: This factor amounts to 14.863 percent of the total variance of barriers to BIM implementation among contracting firms. This factor has five components which include: BIM experts' shortage; the amounts needed to be invested into applying BIM is not clear; insufficient BIM standards and protocols; the time frame of BIM application, and BIM design regulations' amendments. These components have high factor loadings: 0.795, 0.728, 0.702, 0.674 and 0.630, respectively. This study's findings affirmed a few findings of the earlier studies. For instance, Saxon (2013) claimed that only a low number of BIM applications are available in developing countries because construction participants are yet to develop a capability to use BIM. Ezeokoli *et al*. (2016) stated that it is a mere illusion to desire the attainment of purposeful changes without procedures and regulations in place to implement it. Zahrizan *et al*. (2013) found that there are no general regulations regarding BIM implementation, thus each BIM user adopts their own principles without any directive from the vendor which will inevitably result in differences in the level of detail in the implementation in relation to various firms.

Factor 2: Client related issues and high initial BIM capital outlays: This factor amounts to 10.530 percent. This factor has five main components as follows: lack of BIM demand from clients; the cost of the hardware and the BIM software; the cost of BIM software and its updates; the cost of BIM training, and not knowing where to start. These components have factor loadings of 0.773, 0.694, 0.658, 0.625 and 0.598, respectively (see Table IX). This study's findings reveal that there is no motivation for contracting firms to implement BIM as their clients do not request the use of BIM on their construction projects. It can be deduced that, in Nigeria, clients do not demand the use of BIM. This poses a great challenge to BIM implementation, resulting in a very low external force for its implementation. Hence, contracting firms become complacent and consider that BIM implementation is unimportant. This study's findings further confirmed some earlier studies that found that the major impediment to BIM implementation is the huge capital amount that is needed to be expended in setting up the model (which includes the procurement of BIM computer hardware and software packages, the cost of staff training, among other factors) (Young *et al*., 2008; Gardezi *et al*., 2014; Memon *et al*., 2014; Smith, 2014).

Factor 3: Weak BIM skills and resistance to change: This factor amounts to 9.583 percent. The four components are: a lack of BIM personnel and experts for training on the use of BIM software; the fact that BIM requires a complete change of practices and procedures; strong resistance to change, and weak skills among professionals and learning difficulties when learning to use BIM software. As indicated in Table IX, these components have the factor loadings 0.738, 0.701, 0.597 and 0.538 respectively. This study's findings confirm the assertion of Nagalingam *et al*. (2013) that BIM is a new innovation, hence insufficient knowledge and skill relating to this new innovation becomes an impediment to BIM implementation. Kori and Arto (2015) opined that the attitude of construction professionals to change from an existing process to a new one poses more problems than the acquiring of skills. This is because the traditional method of procurement has been used so long that it is extremely difficult to embrace a new process. The delivery of most construction works in Nigeria has been paper-based and, therefore, the implementation of BIM will revolutionize the practices of construction professionals in the industry.

Factor 4: Cooperation issues with managing complicated data: This factor accounts for 9.039 percent (see Table VIII). The factor has three main components which are: weak cooperation among different professions; the need to manage sophisticated data with the BIM model, and a weak knowledge of BIM benefits. The three components have factor loadings of 0.826, 0.674, and 0.505, respectively (see Table IX). These findings indicate that weak cooperation between different disciplines and the weak knowledge of BIM benefits go a long way in affecting BIM implementation among contracting firms.

Factor 5: Lack of BIM tangible benefits and intellectual property related issues: This factor amounts to 8.031 percent (see Table VIII). This factor has two components: the belief that there is no need for BIM application, and issues of intellectual property. The two components have factor loadings 0.807 and 0.571, respectively (see Table IX). These findings indicate that contracting firms are reluctant to implement BIM because there is no clear policy that addresses the issue of intellectual property.

Factor 6: Non-governmental support and BIM working environment related issues: This factor amounts to 7.213 percent. This factor has three main components as follows: no government efforts to implement BIM, issues regarding power supply and weak internet connectivity, and weak education and training. The three components have factor loadings 0.701, 0.602 and 0.562, respectively (see Table IX). These findings affirm the assertion of Smith (2014) who identified that a lack of 'push' via mandates from the government is an impediment to BIM implementation in the construction industry. Alufohai (2012) asserted that the extent of BIM implementation is relatively low in countries where there are no government policies in place to encourage BIM implementation. This finding found that the Nigerian government is not showing any interest in BIM implementation for the delivery of public projects. This particular study finding is contrary to the findings obtained in developed countries, where several governments in developed countries (such as the United Kingdom, United States of America and Australia among others) have set up strategies for the implementation of BIM in their construction works, which has led to rapid BIM implementation (Wong *et al*., 2009; BuildSmart, 2012; UK BIM Strategy Report, 2012). Similarly, the poor state of the electricity supply and other infrastructure is being identified as a significant obstacle in the Nigerian construction industry (Oladapo, 2007). For instance, the lack of constant electricity and the lack of internet connectivity automatically affect the full implementation of BIM, as BIM requires large files; thereby exchanging these files between those working on them poses a challenge in the Nigerian construction industry.

Factor 7: Interoperability issues: This factor amounts to 6.257 percent. This factor has only one component which is the problems relating to interoperability between BIM software packages. As shown in Table IX, this component has a factor loading of 0.697. This study finding has confirmed a similar finding in a few earlier studies. For instance, Boon (2009) opined that interoperability among the software of different developers is a factor that undermines BIM implementation. Azar (2012) claimed that interoperability risks are some of the crucial challenges in the implementation of BIM (between differently used programmes). Zulkipli and Lim (2015) identified a lack of standards relating to interoperability between software due to large data exchange.

Conclusion

BIM plays a crucial role in the performance improvement of contracting firms. There is, therefore, a need to stimulate its implementation in the construction industry, particularly among contracting firms so that they can meet the competitive demands of the construction industry. It is against this backdrop that this study examined the current uptake of BIM implementation among contracting firms in Nigeria (comprising small, medium and large contracting firms), assessed the barriers to BIM implementation in those contracting firms, and examined the ways of improving BIM implementation within those contracting firms. The study revealed the current state of BIM implementation among Nigerian contracting firms in terms of their knowledge of BIM, their usage of BIM as well as the BIM software adopted. Regarding the knowledge of BIM, the study found that 89.41 percent of the respondents' firms have heard about BIM, while 10.59 percent of the respondents' firms have not heard about BIM at all. The study found that 36.47 percent of the firms are using BIM often, 23.53 percent of the firms always use BIM, while 34.12 percent of the firms have never used BIM. Moreover, in relation to the BIM software adopted for use among the contracting firms, the study found that AutoCAD Architecture has the highest percentage of usage with 20 percent followed by Revit Architecture and ArchiCAD with 15 percent each.

In addition, the study identified 25 barriers to BIM implementation in contracting firms. The relative importance of these identified barriers was gauged among Nigerian contracting firms comprising small, medium and large contracting firms. The study revealed the top five ranked barriers to BIM implementation in contracting firms are as follows: the cost of the hardware and

BIM software; not knowing where to start; the cost of BIM software and its updates; problems relating to interoperability, and the cost of BIM training. It is evident from these study findings that a lack of awareness of BIM is no longer a major barrier to BIM implementation in contracting firms. Thus, the major barriers to BIM implementation in contracting firms have shifted to cost and training related barriers. Similarly, the study identified 15 ways of improving BIM implementation in contracting firms. The study indicated the top five ranked ways of improving BIM implementation among contracting firms are: government enforcement of BIM usage; BIM integration into education curricula; BIM skills' development programmes; educating government departments on 'model based' deliverables and their benefits, and the development of BIM forms of contracts for stakeholders.

The study further revealed the Kruskal-Wallis test showed that only two (out of 25) identified barriers, and one (out of 15) identified ways of improving BIM implementation in contracting firms have a significant statistical difference in the rankings among the respondents' groups comprising small, medium and large contracting firms. This implies that there is a common understanding among the contracting firms' categories on both rankings (i.e. on the barriers and on the ways of improving BIM implementation). In addition, the study showed the result of factor analysis that categorized the 25 identified barriers into seven main factors: absence of BIM specialists, standards and protocols; client related issues and high initial BIM outlay; weak BIM skills and resistance to change; cooperation issues with managing complicated data; a lack of BIM tangible benefits and intellectual property related issues; non-governmental support and BIM working environment related issues, and interoperability issues. The study concluded that the awareness of BIM among Nigerian contracting companies is very high and that examining the current state of BIM among the contracting categories will enable the employers in these firms to understand how needful it is to encourage employees to improve their knowledge of BIM, and learn how to implement BIM, as well as advise clients on the benefits and importance of BIM in their projects so as to provide them with more value for their money. The study also concluded that there are ways of improving BIM implementation among contracting categories, thus contracting firms adhering to these ways will positively influence the improvement of BIM implementation in the Nigerian construction industry, and in the construction sector in developing countries at large.

Based on the findings emanating from this study, the following recommendations are proposed:

- There is a need for increased awareness of the benefits of BIM, particularly for public clients who have not shown much interest in the implementation of BIM for the delivery of public projects.
- There is also a need for well-trained professionals in the utilization of BIM in order to ensure increased knowledge of BIM in the Nigerian construction industry.
- There should be a full integration of BIM into the curricula of the architecture, engineering and construction disciplines in higher education institutions as a necessary step towards increased knowledge of BIM. This will ensure that graduates have the background knowledge of the concept, and implementation, of BIM.

- The cost of BIM software should be reduced to a minimal cost and/or subsidised by the Nigerian government as this can also encourage users to learn more about BIM if the software is affordable.
- The government of developing countries should enforce the usage of BIM as a primary requirement in their construction industries.

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List of Figure

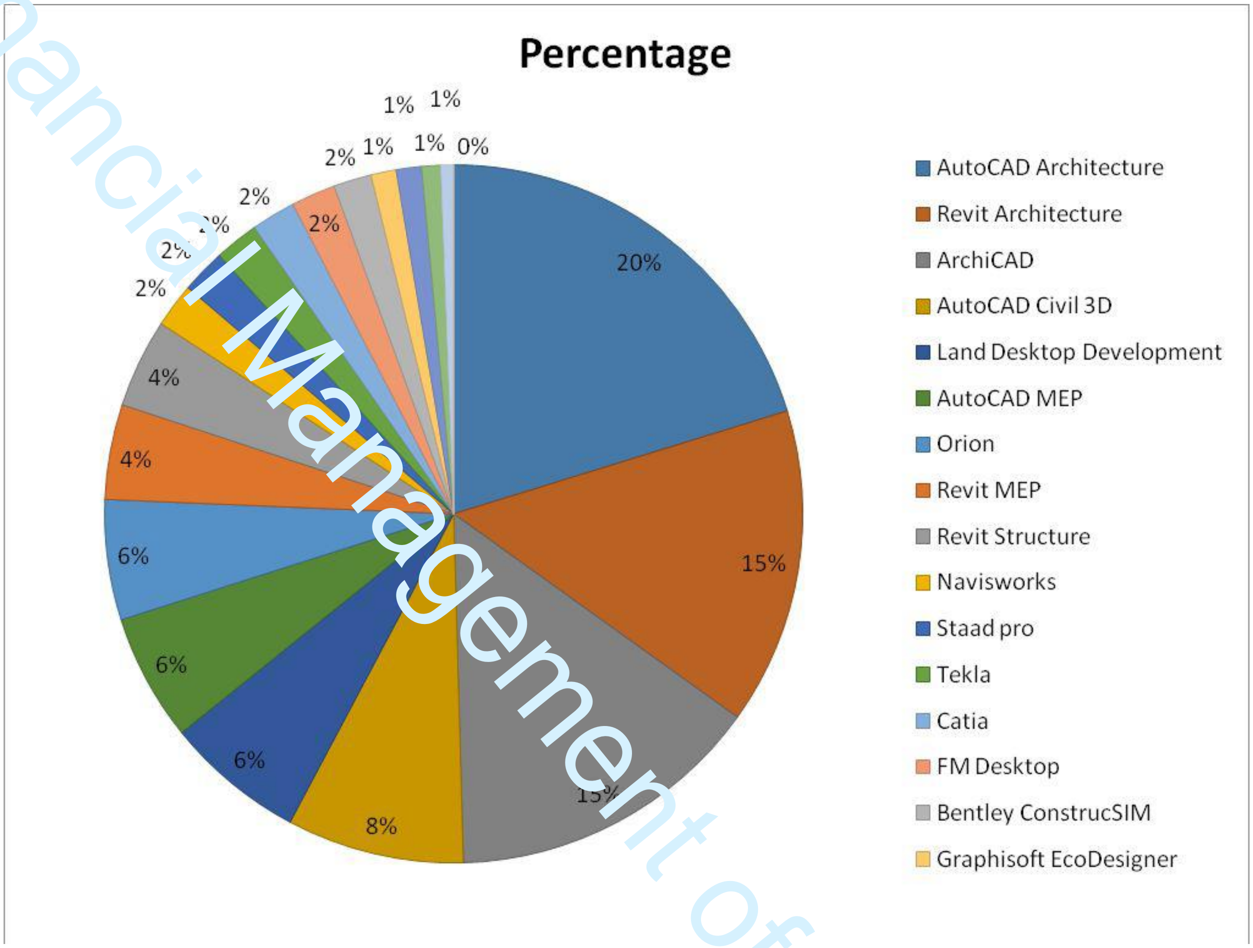

Figure I: BIM software in use within contracting firms

List of Tables

Table I: Identified barriers to BIM implementation in the construction industry

Code	BIM barriers	Reference
B01	Lack of BIM demand from clients	Khosrowshahi and Arayici, 2012; ; Chan, 2014; Azhar et al., 2015; Poirier et al., 2015a; Rodgers et al., 2015
B02	Cost of BIM software and its updates	Gerrard et al., 2010; Khosrowshahi and Arayici, 2012; Abubakar et al., 2014; Forsythe,2014; Azhar et al., 2015; Rodgers et al., 2015
B03	Cost of the hardware and BIM software	Ugochukwu et al., 2015; Kekana et al., 2015; Ruya et al.,2018
B04.	Cost of BIM training	Khosrowshahi and Arayici, 2012; Rodgers et al., 2015; Ruya et al.,2018
B05	Cost of BIM specialists and additional staff recruitment	Khosrowshahi and Arayici, 2012; Abubakar et al., 2014; Rodgers et al., 2015
B06	Time frame of BIM application	Kekana et al., 2015; Ruya et al.,2018
B07	Investment is not clear from the BIM application	Kekana et al., 2015; Poirier et al., 2015b; Ruya et al.,2018
B08	BIM experts' shortage	Gerrard et al.,2010; Chan, 2014; Azhar et al., 2015; Kekana et al., 2015; Rodgers et al., 2015
B09	Insufficient BIM standards and protocols	Kekana et al., 2015; Ruya et al.,2018
B10	Belief that there is no need for BIM application	Khosrowshahi and Arayici, 2012; Forsythe, 2014
B11	Interoperability issues	Khosrowshahi and Arayici, 2012; Forsythe, 2014; Azhar et al., 2015
B12	Weak education and training	Azar, 2011; Ruya et al.,2018
B13	No government efforts to implement BIM	Hassan and Yolles, 2009
B14	Difficulty in managing sophisticated data	Poirier et al., 2015a
B15	Weak cooperation among different professions	Poirier et al., 2015a; Ruya et al.,2018
B16	Issues of intellectual property	Khosrowshahi and Arayici, 2012; Azhar et al., 2015; Kekana et al., 2015
B17	BIM design regulations amendment	Poirier et al., 2015b; Ruya et al.,2018
B18	Development of BIM forms of contract	Kekana et al., 2015; Ruya et al.,2018
B19	Weak knowledge of BIM benefits	Khosrowshahi and Arayici, 2012; Abubakar et al., 2014; Rodgers et al., 2015
B20	Weak skills among professionals and learning difficulty of BIM software	Kekana et al., 2015; Ruya et al.,2018
B21	Lack of BIM personnel and experts for training BIM software	Khosrowshahi and Arayici, 2012; Abubakar et al., 2014; Rodgers et al., 2015
B22	Issues of power supply and weak internet connectivity	Oladapo, 2007; Abubakar et al., 2014; Ruya et al.,2018
B23	Strong resistance to change	Abubakar et al., 2014; zhar et al., 2015; Kekana et al., 2015; Rodgers et al., 2015; Ruya et al.,2018
B24	BIM requires a complete change of practices and procedures	Kekana et al., 2015; Ruya et al.,2018
B25	Not knowing where to start	Gerrard et al.,2010; Forsythe,2014; Azhar et al., 2015; Ruya et al.,2018

Table II: Identified ways of improving BIM implementation in the construction industry

Code	Ways of improving BIM implementation
W01.	BIM integration into education curricula
W02	BIM skills development programs
W03	Feasible ways of migrating from common practice into BIM
W04	Increase the availability of BIM technology
W05	Organized BIM workshops for stakeholders
W06	Undertake pilot projects to validate and demonstrate the BIM benefits
W07	Improvement on BIM interoperability
W08	Communicate lessons learnt from the pilots projects to all stakeholders
W09	Development of BIM forms of contract for stakeholders
W10	Development of BIM intellectual property
W11	Improvement on BIM software standardization
W12	BIM forms of contract with insurance
W13	Educate government departments on 'model based' deliverables and its benefits
W14	Development of BIM warranty requirements
W15	Government enforcement of BIM usage

Table III: Demographic profile of both the firms and respondents

Profile	Frequency	Percentage	Cumulative percentage
Categories of the firm			
Small	35	41.18	41.18
Medium	23	27.06	68.24
Large	27	31.76	100.00
Total	85	100.00	
Numbers of employees			
Small (10-50)	44	51.76	51.76
Medium (51-250)	21	24.71	76.47
Large (251 and above)	20	23.53	100.00
Total	85	100.00	
Specialty of the firm			
Building works	50	58.82	58.82
Civil engineering works	16	18.82	77.64
Engineering services works	2	2.35	79.99
Specialist works	3	3.53	83.52
All of the above	14	16.47	100.00
Total	85	100.00	
Year of firms' establishment			
Up to 10 years	46	54.12	54.12
11-20 years	27	31.76	85.88
More than 20 years	11	12.94	98.82
Others	1	1.18	100.00
Total	85	100.00	
Firms' major client			
Government	36	42.35	42.35
individual/owner	29	34.12	76.47
Private organization	12	14.12	90.59
Others	8	9.41	100.00
Total	85	100.00	
Respondents' professional background			
Architect	29	34.12	34.12
Engineer	23	27.06	61.18
Quantity Surveyor	20	23.53	84.71
Others	13	15.29	100.00
Total	85	100.00	

Profile	Frequency	Percentage	Cumulative percentage
Position of respondents			
Director	2	2.35	2.35
Designer	24	28.24	30.59
Project manager	23	27.06	57.65
Engineer	3	3.53	61.18
Others	33	38.82	100.00
Total	85	100.00	
Respondents' highest academic qualification			
OND (Ordinary National Diploma)	6	7.06	7.06
HND (Higher National Diploma)	15	17.65	24.71
PGD (Post Graduate Diploma)	10	11.76	36.47
BSc	31	36.47	72.94
MSc	19	22.35	95.29
PhD	1	1.18	96.47
Others	3	3.53	100.00
Total	85	100.00	

Table IV: Current state of BIM implementation among contracting firms

	Frequency	Percentage	Cumulative percentage
Have you ever heard about BIM			
Yes	76	89.41	89.41
No	9	10.59	100.00
Total	85	100.00	
If yes above, please select a paragraph			
Worked in firms using BIM	41	53.95	53.95
Read researches related to BIM	16	21.05	75.00
I am training on the use of BIM	13	17.11	92.11
Participated in conferences related to BIM	5	6.58	98.69
Part dealt with in my university	1	1.31	100.00
Total	76	100.00	
Have you used BIM in any of your firms' project			
Yes	56	65.88	65.88
No	29	34.12	100.00
Total	85	100.00	
How often does your firm uses BIM			
Always	20	23.53	23.53
Often	31	36.47	60.00
Once in a while	5	5.88	65.88
Never	29	34.12	100.00
Total	85	100.00	
Type of project used BIM for			
Educational	13	23.22	23.22
Residential	20	35.71	58.93
Industrial	19	33.93	92.86
Public	4	7.14	100.00
Total	56	100.00	

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Table V: Ranking of identified barriers to BIM implementation among contracting firms

BIM barriers	Small firms			Medium firms			Large firms			Total	Total	Kruskal-Wallis
	Mean	SD	Rank	Mean	S D	Rank	mean	SD	Rank	Mean	Rank	Significant
B01. Lack of BIM demand from clients	4.05	1.061	25	4.09	1.005	25	4.30	0.857	7	4.15	23	0.4015
B02. Cost of BIM software and its updates	4.24	0.899	19	4.58	0.664	2	4.55	0.642	2	4.46	3	0.1595
B03. Cost of the hardware and BIM software	4.48	0.615	1	4.52	0.669	6	4.53	0.602	3	4.51	1	0.9314
B04. Cost of BIM training	4.43	0.706	5	4.19	0.921	22	4.61	0.592	1	4.41	5	0.1374
B05. Cost of BIM specialists and additional staff recruitment	4.29	0.774	14	4.32	0.597	13	3.95	0.962	20	4.19	21	0.1051
B06. Time frame of BIM application	4.29	0.802	15	4.33	0.748	12	3.81	1.035	23	4.14	24	0.0310*
B07. Investment is not clear from the BIM application	4.26	0.883	18	4.20	1.160	21	3.71	1.058	25	4.06	25	0.0869
B08. BIM experts' shortage	4.46	0.678	2	4.14	0.935	23	4.04	0.879	16	4.21	18	0.0571
B09. Insufficient BIM standards and protocols	4.29	0.745	16	4.12	0.832	24	3.80	0.980	24	4.24	15	0.0624
B10. Belief that there is no need for BIM application	4.18	0.911	23	4.31	0.995	15	4.23	0.732	9	4.26	14	0.8813
B11. Interoperability issues	4.21	0.784	21	4.54	0.713	3	4.03	0.869	18	4.42	4	0.0692
B12. Weak education and training	4.16	0.731	24	4.59	0.707	1	4.50	0.797	4	4.33	10	0.0930
B13. No government efforts to implement BIM	4.24	0.732	20	4.52	0.622	7	4.22	0.953	11	4.39	6	0.2532
B14. Difficulty in managing sophisticated data	4.46	0.708	3	4.52	0.669	8	4.19	0.857	12	4.22	16	0.2328
B15. Weak cooperation among different professions	4.45	0.766	4	4.31	0.743	16	3.90	0.834	21	4.22	17	0.0343*
B16. Issues of intellectual property	4.34	0.810	10	4.31	0.743	17	3.97	0.796	19	4.21	19	0.2019
B17. BIM design regulations amendment	4.29	0.802	17	4.28	0.957	18	4.04	1.610	17	4.20	20	0.3756
B18. Development of BIM forms of contract	4.32	0.720	11	4.28	0.780	19	3.88	0.978	22	4.16	22	0.0618
B19. Weak knowledge of BIM benefits	4.32	0.753	12	4.26	0.730	20	4.33	0.710	6	4.30	12	0.9461
B20. Weak skills among professionals and learning difficulty of BIM software	4.30	0.716	13	4.51	0.762	9	4.24	0.727	8	4.35	8	0.4704
B21. Lack of BIM personnel and experts for training BIM software	4.41	0.675	7	4.45	0.671	11	4.15	0.814	14	4.34	9	0.2500
B22. Issues of power supply and weak internet connectivity	4.21	0.694	22	4.54	0.800	4	4.10	0.899	15	4.28	13	0.1449
B23. Strong resistance to change	4.43	0.612	6	4.49	0.621	10	4.17	0.702	13	4.36	7	0.2254
B24. BIM requires a complete change of practices and procedures	4.39	0.606	8	4.32	0.649	14	4.23	0.801	10	4.31	11	0.6420
B25. Not knowing where to start	4.39	1.046	9	4.54	0.888	5	4.48	0.848	5	4.47	2	0.6095

Significant at 5%

Table VI: Ranking of identified ways of improving BIM implementation among contracting firms

Ways of improving BIM implementation	Small firms			Medium firms			Large firms			Total mean	Total Rank	Kruskal -Wallis Significant
	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank			
W01.BIM integration into education curricula	4.65	0.483	3	4.60	0.559	6	4.57	0.555	4	4.61	2	0.8297
W02. BIM skills development programs	4.57	0.502	8	4.55	0.565	8	4.67	0.481	2	4.60	3	0.6747
W03. Feasible ways of migrating from common practice into BIM	4.70	0.474	1	4.53	0.619	9	4.37	0.641	11	4.53	6	0.1008
W04. Increase the availability of BIM technology	4.65	0.494	4	4.24	0.827	15	4.43	0.605	10	4.43	14	0.0755
W05. Organized BIM workshops for stakeholders	4.58	0.538	6	4.63	0.651	4	4.37	0.641	12	4.53	7	0.2227
W06.Undertake pilot projects to validate and demonstrate the BIM benefits	4.50	0.615	10	4.51	0.568	10	4.45	0.651	8	4.49	9	0.9331
W07. Improvement on BIM interoperability	4.43	0.612	13	4.64	0.549	3	4.51	0.607	6	4.53	8	0.3994
W08.Communicate lessons learnt from the pilots projects to all stakeholders	4.50	0.615	11	4.60	0.660	7	4.35	0.680	13	4.48	10	0.3717
W09. Development of BIM forms of contract for stakeholders	4.60	0.572	5	4.31	0.768	14	3.99	0.826	15	4.30	15	0.0040*
W10. Development of BIM intellectual property	4.41	0.675	15	4.66	0.484	1	4.28	0.861	14	4.45	12	0.1027
W11.Improvement on BIM software standardization	4.57	0.576	9	4.43	0.669	11	4.45	0.693	9	4.48	11	0.6255
W12. BIM forms of contract with insurance	4.43	0.612	14	4.36	0.751	13	4.52	0767	5	4.44	13	0.7054
W13.Educate government departments on 'model based' deliverables and its benefits	4.68	0.474	2	4.39	0.663	12	4.61	0.552	3	4.56	4	0.1346
W14. Development of BIM warranty requirements	4.49	0.615	12	4.66	0.596	2	4.46	0.707	7	4.54	5	0.4591
W15. Government enforcement of BIM usage	4.58	0.538	7	4.61	0.657	5	4.69	0.527	1	4.63	1	0.6957

Significant at 5%

Table VII: Communalities

BIM Barrier	Communalities Initial	Extraction
B01. Lack of BIM demand from clients	1.000	0.691
B02. Cost of BIM software and its updates	1.000	0.726
B03. Cost of the hardware and BIM software	1.000	0.589
B04. Cost of BIM training	1.000	0.527
B05. Cost of BIM specialists and additional staff recruitment	1.000	0.657
B06. Time frame of BIM application	1.000	0.630
B07. Investment is not clear from the BIM application	1.000	0.737
B08. BIM experts' shortage	1.000	0.716
B09. Insufficient BIM standards and protocols	1.000	0.550
B10. Belief that there is no need for BIM application	1.000	0.712
B11. Interoperability issues	1.000	0.669
B12. Weak education and training	1.000	0.640
B13. No government efforts to implement BIM	1.000	0.762
B14. Difficulty in managing sophisticated data	1.000	0.611
B15. Weak cooperation among different professions	1.000	0.622
B16. Issues of intellectual property	1.000	0.727
B17. BIM design regulations amendment	1.000	0.527
B18. Development of BIM forms of contract	1.000	0.660
B19. Weak knowledge of BIM benefits	1.000	0.643
B20. Weak skills among professionals and learning difficulty of BIM software	1.000	0.623
B21. Lack of BIM personnel and experts for training BIM software	1.000	0.636
B22. Issues of power supply and weak internet connectivity	1.000	0.622
B23. Strong resistance to change	1.000	0.567
B24. BIM requires a complete change of practices and procedures	1.000	0.738
B25. Not knowing where to start	1.000	0.623

Note: Extraction Method: Principal Component Analysis.

Table VIII: Total variance explained for barriers to BIM implementation in contracting firms

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	6.007	24.027	24.027	6.007	24.027	24.027	3.716	14.863	14.863
2	2.962	11.846	35.873	2.962	11.846	35.873	2.633	10.530	25.393
3	1.833	7.333	43.206	1.833	7.333	43.206	2.396	9.583	34.976
4	1.612	6.449	49.655	1.612	6.449	49.655	2.260	9.039	44.015
5	1.531	6.123	55.778	1.531	6.123	55.778	2.008	8.031	52.046
6	1.240	4.960	60.738	1.240	4.960	60.738	1.803	7.213	59.259
7	1.195	4.779	65.517	1.195	4.779	65.517	1.564	6.257	65.517
8	0.989	3.955	69.472						
9	0.915	3.660	73.132						
10	0.883	3.533	76.665						
11	0.775	3.099	79.764						
12	0.724	2.897	82.661						
13	0.594	2.375	85.036						
14	0.530	2.118	87.154						
15	0.446	1.783	88.938						
16	0.425	1.700	90.638						
17	0.405	1.621	92.259						
18	0.365	1.460	93.719						
19	0.358	1.431	95.150						
20	0.311	1.243	96.393						
21	0.258	1.031	97.424						
22	0.192	0.767	98.191						
23	0.181	0.724	98.915						
24	0.151	0.603	99.519						
25	0.120	0.481	100.000						

Note: Extraction Method: Principal Component Analysis

Table IX: Rotated components matrix of barriers to BIM implementation in contracting firms

Barriers	Principal factors						
	1	2	3	4	5	6	7
B08. BIM experts' shortage	0.795						
B07. Investment is not clear from the BIM application	0.728						
B09. Insufficient BIM standards and protocols	0.702						
B06. Time frame of BIM application	0.674						
B16. BIM design regulations amendment	0.630						
B05. Cost of BIM specialists and additional staff recruitment	0.505						
B17. Development of BIM forms of contract	0.496						
B01. Lack of BIM demand from clients		0.773					
B03. Cost of the hardware and BIM software		0.694					
B02. Cost of BIM software and its updates		0.658					
B04. Cost of BIM training		0.625					
B25. Not knowing where to start		0.598					
B21. Lack of BIM personnel and experts for training BIM software			0.738				
B24. BIM requires a complete change of practices and procedures			0.701				
B23. Strong resistance to change			0.597				
B20. Weak skills among professionals and learning difficulty of BIM software			0.538				
B15. Weak cooperation among different professions				0.826			
B14. Difficulty in managing sophisticated data				0.674			
B19. Weak knowledge of BIM benefits				0.505			
B10. Belief that there is no need for BIM application					0.807		
B16. Issues of intellectual property					0.571		
B13. No government efforts to implement BIM						0.701	
B22. Issues of power supply and weak internet connectivity						0.602	
B12. Weak education and training						0.562	
B11. Interoperability issues							0.697