Investigating the barriers to building information modeling (BIM) implementation within the Nigerian construction industry

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Abstract

Purpose – The purpose of this paper is to identify and assess the perceptions of constructional professionals on barriers to implementation of building information modeling (BIM) within the Nigerian construction industry.

Design/methodology/approach – A scoping literature review was conducted to identify the fourteen barriers to implementation of BIM, which were employed to design a questionnaire survey. Data collected were analyzed using descriptive statistics, mean score, Kruskal–Wallis test, analysis of variance and multivariate techniques such as factor analysis.

Findings – The descriptive and empirical analysis demonstrated a disparity of ranking of the 14 barriers factors among the groups; however no statistically significant differences among the 14 barriers to BIM. Based on the mean score ranking results, only three (out of 14) barriers are identified as critical (mean score greater than 3.5): few studies available on BIM and lack of knowledge, inexistence or inadequate government policies, and high cost of implementation. The results of the one-sample *t*-tests show that they were statistically significant differences in 10 out of 14 barriers as follows: few studies available on BIM and lack of knowledge, lack of demand for use and acceptance of BIM, inadequate contractual coordination, lack of specified standards, cost of data and information sharing, technological availability issues, reluctance of other stakeholders, business and cultural changes, data and intellectual property issues, and interoperability issues. The study, through factor analysis, categorized the fourteen barriers to BIM implementation into four principal factors. The factors are: technology and business-related barriers; training and people-related barriers; cost and standards-related barriers; and process and economic-related barriers.

Practical implications – The identification and assessment of the key barriers to BIM implementation would be useful for the construction professionals and other stakeholder of the construction industry with the view to advance BIM adoption in Nigeria. This could also be extended to other developing countries through considerations of the local economic conditions, given the status of BIM as being in the germinating stage of development in Africa.

Originality/value – The study provides insights on the barriers to BIM implementation across the Nigerian construction sector environments. The innovative aspect of the study is the identification of the ordered and grouped (composite) set of barriers to BIM which could be used to developing appropriate mitigating solutions.

Keywords Building information modelling, Construction, Built environment, Nigeria, Barriers

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1. Introduction

Generally, the construction industry is well-known for its long-established non-collaborative work practices (Azhar *et al.*, 2011). Developing countries have also been recognized to be a fertile ground for the AEC industry (Akdag and Maqsood, 2019). Besides, smart cities and sustainable development are not conceivable without substantial efforts from different fields in the industry (Wu and Issa, 2015). Furthermore, a report by World Economic Forum (2018) indicated that the construction industry accounts for nearly 6% of the World's GDP. According to a research by Banawi (2017), it was indicated that 75% of waste comes from construction activities and buildings are responsible for 40% of carbon emissions. It was also revealed that projects could perform better in terms of cost, time and quality with the adoption of emerging technologies like building information modeling (BIM). Gledson *et al.* (2012) also expressed that the construction industry is slow in adapting to modern technologies as against the manufacturing industry. Technologies such as Artificial Intelligence (AI), Sustainability, Prefabrication, Building Information Modeling (BIM), Business Process Reengineering (BPR), Total Quality Management (TQM), among others have been deployed to facilitate the integration of construction processes and achieve value for money (Saka and Chan, 2019a).

BIM has been highlighted by the Architecture, Engineering, and Construction (AEC) industry as a powerful design and management tool that has significant advantages over the building life cycle, design and management (Yan and Damian, 2008). Furthermore, BIM is described as a digital representation of physical and functional characteristics of a facility creating a shared knowledge resource for information about it forming a reliable basis for decisions during its life cycle, from earliest conception to demolition (Eastman *et al.*, 2011; Snook, 2011; Suranga; Weddikkara, 2012).

BIM provides solutions to the numerous problems such as building element clash, lack of collaboration between project team, inefficient information flow, inherent in the construction industry (Eastman *et al.*, 2011; Latiffi *et al.*, 2013; Kushwaha, 2016; Kong *et al.*, 2020), with the dynamic nature of the construction industry to accommodate more challenges and complexity as the needs of the clients requires. For instance, BIM has made it easy for designers to easily spot clash of building elements by simply running clash detection analysis on the BIM model. In same vein, BIM has made it easy for project team to collaborate effectively on same platform and thus guarantee efficient flow of information. Studies have also shown that individual perception of BIM technology impacts BIM adoption negatively.

Latiffi *et al.* (2013) also identified the implementation of BIM as a precursor to overcoming the following construction-related problems: delay, clash of design by different professionals and construction cost overrun. Similarly, Kong *et al.* (2020) identified time, cost and design related issues. These identified challenges which not only affect developing countries, but developed economies have largely contributed to the lack of BIM adoption among the Nigerian construction professionals. A number of non-technical (i.e. human and organizational culture) and technical (i.e. technology) challenges have also been identified as affecting the implementation of BIM (Musa *et al.*, 2019). Likewise, Saka and Chan (2019a) identified the people/process-related barriers amongst the major challenges facing BIM adoption in Africa. Challenges such as people, process and technology have been found to impede an effective adoption rate in Malaysia (Enegbuma *et al.*, 2014). However, Usman (2015) emphasized that individuals' readiness presents a greater setback to BIM than the management, process, and technology involved in its adoption. Despite the huge benefits that could be derived from the implementation of BIM in Nigeria, especially by cutting capital cost on construction projects, reducing risks occurrence and delivering sustainable construction projects, it is mostly used in the schematic design stage by Architects and Engineers to produce drawings (Onungwa and Uduma-Olugu, 2016; Banawi, 2017). Saka and Chan (2019b) also affirmed that Africa are lagging in the BIM research, Australia and Asia are growing, while Europe and North America are ahead. In addition, the study by Anifowose *et al.* (2018) aimed at assessing the adoption level of BIM by the selected Nigerian professionals in the built environment, revealed that 40% of the professionals are familiar with BIM concept and the technology is still at its infant stage. Also, the study indicates a decline in the awareness of

BIM uses from design down to post construction stage. Despite that finding, the respondents nevertheless acknowledged that the studies on BIM within the Nigerian context were limited, and lack of requisite knowledge served as the major deterrent to BIM adoption.

Recently, there have been studies regarding BIM barriers in developing countries like Ghana (Oteng *et al.*, 2018), Pakistan (Akdag and Masqood, 2019) and Yemen (Gamil and Rahman, 2019) but little research has been carried out in Nigeria context (Amuda-Yusuf *et al.*, 2017; Anifowose *et al.*, 2018; Hamma-adama and Kouider, 2019; Babatunde and Ekundayo, 2019; Babatunde *et al.*, 2020a). Whist there have been some studies on BIM within the Nigerian context, these have been limited to exploring the barriers to the incorporation of BIM into quantity surveying (QS) undergraduate curriculum in Nigerian universities, albeit from the lenses of students and academics (Babatunde and Ekundayo, 2019); identification of measures to improve the usage of BIM in the Nigerian building industry (Onungwa *et al.*, 2017); assessment of the BIM training gaps (Oyewole and Dada, 2019); impact of BIM on collaboration (Onungwa and Uduma-Olugu, 2016); BIM awareness (Olapade and Ekemode, 2018); Barriers to BIM in SMEs (Saka and Chan, 2020); Benefits (Olawumi and Chan, 2019a), and drivers / barriers for BIM implementation (Babatunde *et al.*, 2019; Babatunde *et al.*, 2020a). More so, the higher levels of BIM awareness in Nigeria do not necessarily translate into implementation (Saka and Chan, 2019c). On the other hand, other studies including (Gamil and Rahman, 2019; Addy *et al.*, 2018; Olawumi and Chan, 2019b) have highlighted the importance of awareness of BIM, and need for investigating the barriers, and antecedents in developing countries, and development of benchmarking model that will enhance BIM. However, there is limited knowledge on the barriers to implementation of building information modelling (BIM) within the Nigerian construction industry, viewed from the construction professional's lenses. Hence, in order to fill the identified knowledge gap, this study is aimed at investigating the barriers to the implementation of BIM in the Nigerian construction industry.

The structure of this paper is as follows: First, the following section will summarize and present the extant literature on barriers to the implementation of building information modelling; drawing on the perceived strengths of a scoping review, a brief discussion of the gaps in knowledge will be presented. Then, after explaining the research methodology and justification for the chosen data analysis and collection techniques, the results and findings are discussed. The final section addresses the implications, conclusions made and recommendations.

2. Perceived barriers to BIM adoption

Aranda-Mena *et al.* (2009) revealed the issues associated with the interoperability of different software used for BIM as one of the major deterrent factors toward BIM usage. Interoperability Issues arose as a crucial matter in the building, designing and lack of intellect in data interpretation by different software or their inability to interpret the Industry Foundation Classes (IFC) data (Singh *et al.*, 2017). Similarly, Ku and Taeibat (2011) also revealed that different software being used cannot easily communicate with each other thus information stored in some software has to be stored again on software instead of being linked together which is the primary motive of using BIM. This has in no small way discouraged the adoption of BIM by some professionals and clients who are of the belief that re-entry of the data nullifies the numerous benefits BIM might have on project delivery (Nanajkar and Gao, 2014). Finally, recent studies such as Vidalakis *et al.* (2020) have identified BIM software support systems amongst SMEs as being particularly low.

Due to the uniqueness of the nature of data encapsulated in BIM Models, legal concerns have risen as to who bears ownership of the multiple designs, fabrication, analysis and construction datasets (Rosenberg, 2007; Ibrahim and Abdullahi, 2016). Also, part of the issues which arises is the level of accountability for the accuracy expected from each professional and who is to be held responsible for non-accuracy of design (Aranda-Mena *et al.*, 2009; Thompson and Miner, 2006). In the traditional paper-based design method, the architect can be held responsible for his drawings same with the Engineers and other professionals but on the BIM Platform such culpability cannot be easily ascertained.

Thompson and Miner (2006) indicated that BIM being a relatively new concept will involve expenditure on software, training and time. But the costs need to be weighed against the potential benefits. Furthermore, Isa (2015) stated that unavailability of technological capacity to implement BIM is the major barrier facing the adoption of BIM in Nigeria. This was also corroborated by Usman (2015), who enunciated that despite the proliferation of different research studies on BIM and its Model, adoption is still relatively low because of the absentia of the technological aspects required. Abubakar *et al.* (2014) also emphasized that not only is the technology unavailable, but the requisite software needed for use by professionals are also largely beyond their reach. Consequently, some professionals with access to such software have with issues with its licensing which can be exorbitant considering its small scaled use by a single professional. This is in contrast to licensing for a company or firms which is more economical.

BIM adoption is far more than just replacing a 2D or 3D CAD environment with a building model system as it involves acquiring software, training and upgrading hardware (Ibrahim and Abdullahi, 2016). Effective usage of BIM of requires that changes be made to virtually every aspect of a firm's business and its mode of operation. These changes would require some understanding of BIM technology and related processes and a plan for implementation before conversion can begin (Azhar *et al.*, 2008). The implementation of BIM brings wholesome changes which is dreaded by some professionals and companies because they lack the capacity to implement and successfully manage such transitional changes as the specific changes for each firm depends on their sector of operation (Abubakar *et al.*, 2014; Rogers *et al.*, 2015).

The growing propagation of non-standardized BIM applications by myriads of software developers (Smith and Tardif, 2009) is a major problem facing companies in adopting BIM. These companies are caught between choosing which standards to follow as different countries have their standards for BIM, thus a country like Nigeria without its own localized BIM standards have to import standards for their BIM usage from other countries (Bin Zakaria *et al.*, 2013), and this can as well lead to conflicting standards among professionals working on a particular project within the country. Foster (2011) also stated that absence of standard document causes companies to shrink back in their BIM adoption ideas (Chan, 2014).

Studies such as Chan (2014) and BuildingSMART (2011), observed that lack of trained and skilled personnel inhibits BIM adoption. Aranda-Mena *et al.* (2009), also said that where there are no personnel to champion the adoption of BIM, there is no issue talking about its adoption as the people to carry out such are non-existent in such areas. Hence, in an area where there is a dearth of professionals with skill and training as required adoption is on a mirage. Sebastian (2011) opined that where the contract processes are not well coordinated and organized it presents great difficulty for BIM to be adopted for such projects, as the whole contractual process is not well structured to contain such innovative technology. Thompson and Miner (2006) also postulated that contractual coordination is a criterion for BIM adoption, thus if a project is not adequately coordinated and the processes well defined, BIM cannot be adopted on such because adoption of BIM must be planned into the contract from its inception.

Given the changes required to be effected before BIM can be successfully implemented; this has made some companies to shy away from BIM. The most significant changes that companies face when implementing BIM technology is intensively using a shared building model during design phases and coordinated set of building models during construction and fabrication, as the basis of all work processes and for collaboration (Ku and Taiebat, 2011; Ibrahim and Abdullahi, 2016). Also, some professionals are yet to come around and accept BIM as a viable alternative to the traditional method as such professionals may see absolutely nothing wrong with the traditional construction methods (Ibrahim and Bashir, 2012). Nigeria, like most developing countries in sub-Saharan Africa does not have an existent government policy or intervention effort aimed at encouraging the adoption and knowledge of BIM. This is in contrast to what is obtainable in developed countries like UK, China, USA, etc. (Ibrahim and Bashir, 2012; Aluhofai, 2012). This absence of such governmental organization has discouraged other private investors from taking BIM adoption efforts serious as government still remains the major client for projects; thus, they are expected to take the initiative for other investors to follow (Chewlos *et al.*, 2001).

Demand for a product is known to compel supply of such, but where there is no demand for a product supply is unwarranted. This is same with the Use of BIM, if clients do no't demand for its use hence (Yan and Damian, 2008); the professionals and companies will see no need to implement it. In the long run, professionals with knowledge of and zest for BIM adoption are forced to abandon the concept for the traditional method just to follow the trend of industry demand (Khosrowshahi and Arayici, 2012). BIM with its supposed advantages would have no effect on the construction industries if the clients continuously demand for the use of traditional method for their projects (Ibrahim and Bashir, 2012). This singular factor has made professionals abandon the idea of obtaining BIM trainings and Certification. Marefat *et al.* (2019) addressed the factors that lead to failure in the adoption of BIM in Iran to be; lack of well-trained personnel, proper social infrastructure, guidance and governmental supports. Similarly, Zhou *et al.* (2019) revealed six barriers to BIM implementation in China which adequate attention have not been given to and they include; insufficient government lead/direction, organizational issues, legal issues, high cost of application, resistance to change of thinking mode and insufficient external motivation.

Ayinla and Adamu (2018) identified six themes which includes; cost, culture, expertise, technology and interoperability, client demand, and legal issues to discuss the issues with BIM adoption. Al-Yami and Sanni-Anibire (2019) also highlighted lack of policy initiatives and research domain as the barrier to BIM adoption in Kingdom of Saudi Arabia. Almuntaser *et al.* (2018) examined the challenges faced by Saudi Arabian AEC firms to include; lack of interest by clients and industry stakeholders, inadequate experience of the BIM team, and lack of mentorship from a BIM champion. Similarly, Gamil and Rahman (2019) findings revealed the most critical challenges to BIM adoption to include; financial restrictions, lack of BIM knowledge, improper introduction of BIM concepts, lack of awareness of BIM benefits and no governmental enforcement. Summarily, the adoption of BIM is bedeviled by deterrent factors, some of which are based on the geographic location, economic state of the nation, government policy, and disposition to change. Some of these barriers as highlighted by different researchers were collated and presented in Table 1.

In order to guarantee that all the barriers in practice, and particularly pertinent to the developing countries were identified; the studies were selected using a mini scoping review. According to Grant and Booth (2009), this type of review is used for preliminary assessment of potential size and scope of available research literature, with no formal quality assessment required. The SCOPUS database was used, and the following keywords of "Building information modelling" AND "Barriers" resulted in 240 documents 65 articles published between 2009 and 2019, and article or review (document types). These studies comprised 69 articles from open access and 171 from other sources. The results also showed that of the articles were published in *Engineering, Construction and Architectural Management* (10) followed by *IoP Conference Series Materials Science and Engineering* (9), and *Automation in Construction* (8). Interesting, with the exception of China (Zhou *et al.*, 2019); and Iran (Marefat *et al.*, 2019), none of the 10 studies were drawn from developing countries such as Nigeria. The

S/N	Barriers	Sources
1	Interoperability issues	Ku and Taiebat (2011); Nanajkar and Gao (2014); Rogers *et al.* (2015); Aranda-Mena *et al.* (2009); Ayinla and Adamu (2018); Raouf and-Ghamdi (2019)
2	Data and intellectual property issues	Rosenberg (2007); Thompson and Miner (2006); Aranda-Mena *et al.* (2009)
3	High cost of implementation	Thompson and Miner (2006); Nanajakar and Gao (2014); Zhou *et al.* (2019); Ayinla and Adamu (2018); Gamil and Rahman (2019); Raouf and-Ghamdi (2019)
4	Technological availability issues	Isa (2015); Usman (2015); Ayinla and Adamu (2018)
5	Lack of specified standards	Bin Zakaria *et al.* (2013); Chan (2014)
6	Software availability issues	Abubakar *et al.* (2014); Zhou *et al.* (2019); Vidalakis *et al.* (2020)
7	Business and cultural changes	Abubakar *et al.* (2014); Rogers *et al.* (2015); Azhar *et al.* (2008); Marefat *et al.* (2019)
8	Cost of data and information sharing	buildingSMART (2011); Abubakar *et al.* (2014); Rogers *et al.* (2015)
9	Lack of training and skills	Ku and Taiebat (2011); BuildingSMART (2011); Chan (2014); Aranda-Mena *et al.* (2009); Marefat *et al.* (2019); Almuntaser *et al.* (2018)
10	Reluctance of other stakeholders	Ku and Taiebat (2011); Zhou *et al.* (2019)
11	Inexistence or inadequate government policies	Chewlos *et al.* (2001); Ibrahim and Bashir (2012); Marefat *et al.* (2019); Zhou *et al.* (2019)
12	Inadequate contractual coordination	Thompson and Miner (2006); Sebastian (2011)
13	Lack of demand for use and acceptance of BIM	Khosrowshahi and Arayici (2012); Yan and Damian (2009); Chewlos *et al.* (2001); Ibrahim and Bashir (2012); Zhou *et al.* (2019); Ayinla and Adamu (2018)
14	Few studies available on BIM and lack of knowledge	Bin Zakaria *et al.* (2013); Hatem *et al.* (2018); Almuntaser *et al.* (2018); Gamil and Rahman (2019); Saka and Chan (2019c)

Table 1. Summary of selected studies on perceived barriers to BIM implementation

search was further refined using the keyword of "Developing countries" resulting in 21 articles from open access and 29 from other sources. Revisiting the first query search by using the keyword of "Nigeria" (i.e. (TITLE-ABS-KEY ("Building information modelling" AND Barriers)) AND ("Nigeria") resulted in a total 10 articles with 3 articles from open access and 7 from other sources. The final selected 14 barriers were identified through reading the abstracts with key focus on the identified keywords. The final query string was therefore as follows: (TITLE-ABS-KEY ("Building information modelling" AND Barriers)) AND ("Developing countries"). The above results highlight the need for undertaking further investigations into the barriers affection the implementation or adoption of BIM. Furthermore, despite a plethora of studies on the barriers to BIM, there is still lack of studies which explore the latent structure of barriers to BIM implementation in a developing country like Nigeria. Therefore, the current research adopts the factor analysis to uncover the latent structure of barriers was carried out to address the identified literature gap.

3. Research methodology

As indicated in Figure 1, the research process for this study is divided into four distinctive processes namely; literature survey, questionnaire design and distribution, questionnaire collection and data analysis, and presentation of result.

3.1 Measurement instrument

To achieve the objectives of this study, the research approach adopted involved a questionnaire survey which was conducted to investigate the levels of agreement amongst

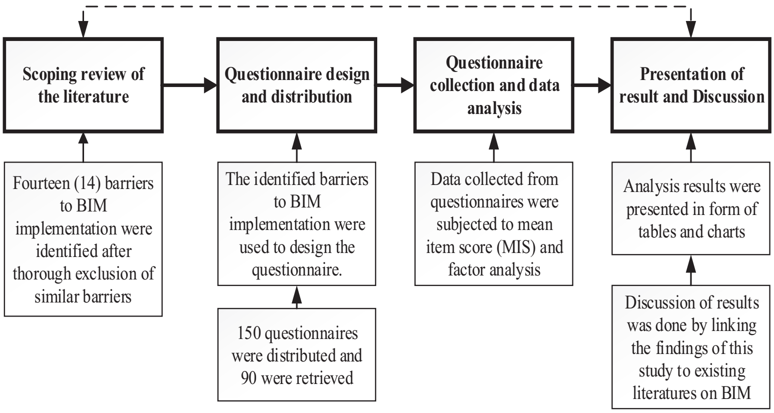

Figure 1.
Research process

the Nigerian professionals on the barriers to implementation of building information modelling (BIM). The identification of the barriers was carried out through a literature review. The quantitative approach (questionnaire surveys) was adopted for this study because it involves the generation of data in quantitative form which can be subjected to rigorous quantitative analysis in a formal and rigid fashion (Kothari, 2004). Furthermore, the review of relevant literature resulted in formulation of a structured questionnaire based on 5-point Likert-scale measurement. Collins (2010) maintains that Likert scales are effective to elicit participants' opinions on various statements. Furthermore, as acknowledged by Albaum (1997), this scale was adopted due to its ability to detect the feelings that respondents have about their attitudes

3.2 Survey administration

Questionnaires were administered to the relevant built environment professionals in top construction companies based in Lagos, the commercial City of Nigeria. The goal of sampling is to provide a realistic means of enabling the data collection and processing component of research to be carried out (Kothari, 2004). The study adopted random sampling technique which gives every professional within Lagos the opportunity of being selected. A recent research by Shurrab *et al.* (2019) also adopted this sampling approach to select their respondents. The scope of this study was limited to Lagos State due its remarkable growth and demands for infrastructure development. A recent study revealed that Lagos State has received huge investments over the years which includes; Lekki free trade zone, Eko Atlantic city, Dangote petroleum refinery, Island international airport Lekki and deep sea port (Ogunde *et al.*, 2017).

Questionnaires were distributed to the construction professionals by means of e-mail invitation, inviting them to fill in and submit the web–based questionnaire (Google Forms). A total of one hundred and fifty (150) questionnaires were distributed, ninety (90) were completed and returned, and this resulted in a response rate of 60%. The response rate achieved in this survey provides reasonable data for analysis based on Collins (2010).

3.3 Data analysis

IBM SPSS version 23 was used for data analysis. The study adopted descriptive and inferential statistics to analyse data obtained from respondents. Reliability test was carried out for all the BIM implementation barrier variables used in this study. When using Likert scales, it is imperative to calculate and report Cronbach's *alpha* coefficients as well as the internal consistency and reliability (Maree, 2016). Maree and Pietersen (2016) suggest that the following guidelines for the interpretation of Cronbach's *alpha* coefficient: 0.90 – high reliability; 0.80 – moderate reliability, and 0.70 – low reliability. The reliability test for the 14 variables revealed a Cronbach's *alpha* coefficient of 0.842 which is considered reliable. The mean item score of each variable was calculated and ranked accordingly. Factor analysis was used to categorize the implementation barriers of BIM into groups.

Mean score (MS) was used to describe the relative rankings of the implementation barriers of BIM from all the respondents in descending order of importance. Recent research on BIM implementation barriers like Zhou *et al.* (2019) and Gamil and Rahman (2019) have adopted this method. It is represented mathematically below in Eqn (1);

$$\text{Mean Score(MS)} = \frac{\sum(f \times s)}{N}, \ (1 \leq \text{MS} \leq 5) \tag{1}$$

where s = Score given to each factor by the respondents and ranging from 1 to 5 where "1" means "strongly disagree" and "5" means "strongly agree." f = Frequency of responses to each rating (1–5), for each factor N = Total number of responses concerning that factor.

SD was calculated to obtain the dispersion of the responses regarding the implementation barriers of BIM among all the professionals. SD is calculated by using the following formula in Eqn (2):

$$\sigma = \sqrt{\frac{\sum(x - \bar{x})^2}{n - 1}} \tag{2}$$

where σ = standard deviation, $\bar{x}$ = mean score

3.3.1 Reliability analysis. In examining the reliability and consistency internally for the ranking of the results with the Likert-type scale method, Cronbach's Alpha Reliability Test (CART) was employed (Santos, 1999). This test was applied in a bid to assess the validity of the results acquired through the questionnaire survey. The Cronbach's alpha coefficients range from 0 to 1 in value. The threshold reliability coefficient alpha value is 0.70, which means the higher score indicating the adopted measurement scale is reliable (Santos, 1999).

CART is calculated by using the following formula in Eqn (3) (Cronbach, 1951, p. 299):

$$\alpha = \frac{n}{n-1}\left(1 - \frac{\sum i V_i}{V_t}\right) \tag{3}$$

where, n = the number of items

V_t = the variance of the total scores V_i = the variance of the item scores

Factor analysis involves multivariate statistical procedures that are employed for various multi-faceted purposes; part of which includes the reduction of a large number of variables into a smaller set of variables (factors) (Williams *et al.*, 2010).

4. Results and discussions

4.1 Characteristics of respondents

Table 2 presents respondents' characteristics according to their profession, academic qualification, and working experience.

4.1.1 Profession background. Table 2 shows the professions of the respondents, 24% were quantity surveyors having a majority, followed by Builders and Civil Engineers with 20%,

Demographic information	No of respondents	%	Cumulative
Professional background			
Quantity surveyor	22	24.4	24.4
Architect	17	18.9	43.3
Estate surveyor	15	16.7	60.0
Builder	18	20.0	80.0
Civil engineer	18	20.0	100.0
Academic qualification			
Ordinary national diploma	3	3.3	3.3
Higher national diploma	30	33.3	36.7
Bachelor's degree	36	40.0	76.7
Master's degree	20	22.2	98.9
Doctorate degree	1	1.1	100.0
Experience (in years)			
0–5	29	32.2	32.2
5–10	36	40.0	72.2
11–15	11	12.2	84.4
16–20	9	10.0	94.4
Over 21	5	5.6	100.0

Table 2. Respondents' demographic profile

following closely by Architects with 19% and Estate Surveyors with 17%. The major professions in the Nigerian construction industry are well represented.

4.1.2 Academic qualifications. As can be seen from Table 2, the minorities (1%) of the respondents were doctorate degree holders, 40% had bachelor's degree, 34% were Higher National Diploma holders, 22% were Master's Degree holders, and 3% were National Diploma holders. The revealed that the respondents are adequately educated to provide meaningful information for this research.

4.1.3 Experience. Table 2 shows the working experience of the respondents, 40% of the respondents have 5–10 years of working experience, 32% had less than 5 years working experience, 12% had 11–15 years, 10% had 16–20 years with the lowest being 21 years and above having 6%. This connotes that the respondents are well experienced to provide valuable information for this research.

4.2 Ranking of barriers to BIM implementation

Table 3 shows the ranking of the fourteen barriers to BIM implementation according to the mean scores in descending order. Table 2 also shows that the majority (71.4%) of the hypothesized barriers are perceived as statistically significant ($p < 0.05$) by the respondents using the one-sample t-test value of 3.5. The mean score of the barrier ranges between 2.822 and 3.756. Examination of the values of the different maximum and minimum score (not reported), and the results further suggested that the data was not biased. These BIM implementation barriers ranged from "Few studies available on BIM and lack of knowledge" (mean = 3.756; SD = 0.964; $t\,(89) = 2.516$; $p = 0.014 < 0.05$) which is the highest ranked to "Interoperability issues" (mean = 2.822; SD = 0.881; $t\,(89) = -7.294$; $p = 0.000 < 0.05$) which is the least ranked. To get the most significant BIM implementation barriers in the Nigerian construction industry based on the mean score, a threshold of 3.50 was set. This same threshold approach was used in Okorie and Olanrewaju (2019) to assess the significant variables. As a result, only three (3) BIM implementation barriers were above 3.50 and considered significant. These implementation barriers include: "Few studies available on BIM and lack of knowledge" (mean = 3.756; SD = 0.964; $t\,(89) = 2.516$; $p = 0.014 < 0.05$),

S/N	Barriers	MS	SD	*t*-value ($\mu = 3.5$)	df	Sig. (2-tailed)	Mean difference	*R*	Significant ($p < 0.05$)
B14	Few studies available on BIM and lack of knowledge	3.756	0.964	2.516	89	*0.014**	0.25556	1	Yes
B11	Inexistence or inadequate government policies	3.567	1.061	0.596	89	0.552	0.06667	2	No
B3	High cost of implementation	3.533	0.902	0.351	89	0.727	0.03333	3	No
B9	Lack of training and skills	3.456	1.083	−0.389	89	0.698	−0.04444	4	No
B6	Software availability issues	3.344	1.123	−1.314	89	0.192	−0.15556	5	No
B13	Lack of demand for use and acceptance of BIM	3.289	0.927	−2.160	89	*0.033**	−0.21111	6	Yes
B12	Inadequate contractual coordination	3.222	1.036	−2.543	89	*0.013**	−0.27778	7	Yes
B5	Lack of specified standards	3.200	1.019	−2.793	89	*0.006**	−0.30000	8	Yes
B8	Cost of data and information sharing	3.189	1.037	−2.845	89	*0.006**	−0.31111	9	Yes
B14	Technological availability issues	3.178	0.967	−3.162	89	*0.002**	−0.32222	10	Yes
B10	Reluctance of other stakeholders	3.111	1.043	−3.536	89	*0.001**	−0.38889	11	Yes
B7	Business and cultural changes	3.089	1.148	−3.397	89	*0.001**	−0.41111	12	Yes
B2	Data and intellectual property issues	3.078	1.094	−3.662	89	*0.000**	−0.42222	13	Yes
B1	Interoperability issues	2.822	0.881	−7.294	89	*0.000**	−0.67778	14	Yes

Note(s): SD = Standard Deviation; *R* = Rank; Sig. = Level of significance; MS = Mean score of the BIM implementation barriers where 5 = strongly agree; 4 = agree; 3 = neutral; 2 = disagree; 1 = strongly disagree. The higher the mean score the more severe the barrier; df = degrees of freedom, *Significant at the 95 per cent level ($p < 0.05$).

Table 3. Ranking of BIM implementation barriers

"Inexistence or inadequate government policies" (mean = 3.567; SD = 1.061; t (89) = 0.596; $p = 0.552 > 0.05$), and "high cost of Implementation" (mean = 3.533; SD = 0.902; t (89) = 0.351; $p = 0.727 > 0.05$). On the other side, significant variables were also judged using the level of significance (p-value) of the data obtained from each variable. In this case, only ten variables were found to be significant which include, few studies available on BIM and lack of knowledge ($p = 0.014$), Lack of demand for use and acceptance of BIM ($p = 0.033$), inadequate contractual coordination ($p = 0.013$), lack of specified standards ($p = 0.006$), cost of data and information sharing ($p = 0.006$), technological availability issues ($p = 0.002$), reluctance of other stakeholders ($p = 0.001$), business and cultural changes ($p = 0.001$), data and intellectual property issues ($p = 0.000$), and interoperability issues ($p = 0.000$).

The two approaches revealed a total of 12 significant barriers to BIM implementation which include the following; Few studies available on BIM and lack of knowledge, inexistence or inadequate government policies, high cost of implementation, lack of demand for use and acceptance of BIM, inadequate contractual coordination, lack of specified standards, cost of data and information sharing, technological availability issues, reluctance of other stakeholders, business and cultural changes, data and intellectual property issues, and interoperability issues. Almost all the identified barriers from literature were considered significant, this simply means they have serious effect on the implementation of BIM in the Nigerian construction industry. A research by Gerges *et al.* (2017) revealed that only 20% of AEC organizations are using BIM or are involved in BIM adoption process in any capacity in the Middle East despite having high number of BIM projects. Furthermore, the research also revealed cost and resistance to change as one of the major obstacles in adopting BIM in the area (Gerges *et al.*, 2017). In same vein, Ku and Taiebat (2011) findings discovered the major barriers to BIM implementation to be; learning curve and lack of skilled personnel, high cost to implementation, reluctance of other stakeholders, lack of collaborative work processes and modeling standards, interoperability, and lack of legal/contractual agreements. Similarly, Zhou *et al.* (2019) revealed three topmost barriers to BIM implementation in China to be; lack of standards and regulations, and lack of applicability and practicability regarding the BIM software. Another research by Eadie *et al.* (2014) highlighted doubts about ROI and lack of vision of benefits as the topmost barriers to BIM implementation in the UK Table 4 shows a comparison of the current study findings in relation to previous research works in UK, Middle East, China, and Yemen. Cost/finance related barrier takes same third position in the current study, Eadie *et al.* (2014), and Gerges *et al.* (2017) while it takes first position Gamil and Rahman (2019) which indicates that cost/finance plays major role in the implementation of BIM for construction practices.

4.3 Kruskal Wallis (one-way analysis of variance (ANOVA))

In order to examine any differences in the perceptions of the respondent professional background (Quantity surveyors, Architects, Estate surveyor, Builder and Civil engineer) on the criticality of the barriers to BIM implementation, a Kruskal Wallis one-way between groups ANOVA was conducted to test the hypothesis of no significant difference based on the professional background. Prior to that, the Kolmogorov–Smirnov test was used for ascertaining the normality of the data distribution. The significance level of the analysis was set at 0.05 as utilized by Shokri-Ghasabeh and Chileshe (2016) and similar studies such as Babatunde and Ekundayo (2019). The results of the Kruskal Wallis one-way ANOVA for K independent samples are summarized in Table 5. The results of the data sets showed that the BIM barriers were not normally distributed at 95% confidence interval.

Examination of Table 5 shows that there is no statistically significance difference of opinion in the rankings at the $p > 0.05$ level of the 14 barriers to the implementation of BIM. This finding demonstrates that irrespective of the respondent's professional background, there was agreement amongst them in the ranking of these barriers. Table 5 further shows that both the Architects and Estate surveyors also rated this barrier of "few studies available on BIM and lack of knowledge" as highly ranked (mean score = 4.056, std = 0.966) and (mean score = 4.067, std = 0.961) respectively, the Quantity surveyors ranked "Lack of training and skills" first (mean score = 3.727, std = 0.985). In contrast, the builders and Civil engineers ranked "Data and intellectual property issues" and "High cost of implementation" first with (mean score = 3.667, std = 0.850) and (mean score = 3.611, std = 0.840) respectively. In contrast, the QS, Architects, Estates surveyors and Civil engineers ranked "Data and intellectual property issues" 13th, 12th, 14th and 12th respectively. Despite the disparity in the ranking of this barrier as shown in Table 5, no significant differences were found as evidenced by the results of the Kruskall-Wallis one-way analysis of variance (ANOVA) for "Data and intellectual property issues" ($p = 0.104 > 0.05$). The findings are further consistent with previous studies which identified training gaps in adopting BIM with quantity surveyors amongst the construction professionals in most need (Oyewole and Dada, 2019).

S/N	Author	Region	Country	Ranking method	Barrier	
1	Current study	Africa	Nigeria	MS	Few studies available on BIM and lack of knowledge	*3.756*
					Inexistence or inadequate government policies	*3.567*
					High cost of implementation	*3.533*
2	Eadie *et al.* (2014)	Britain	United Kingdom	MS	Doubts about ROI/Lack of vision of benefits	*3.053*
					Scale of culture change required/Lack of flexibility	*2.737*
					Cost of Training	*2.684*
3	Gerges *et al.* (2017)	Middle East	Egypt, United Arab Emirates, Saudi Arabia, Qatar, Oman, Bahrain, Lebanon, Jordan, and Kuwait	Index	People comparing BIM to CAD	*82*
					Resistance of change	*82*
					Contractor looks at BIM as additional cost	*81*
4	Zhou *et al.* (2019)	Asia	China	MS	Lack of standards and regulations	*4.590*
					Legal issues	*4.410*
					Lack of applicability and practicability regarding the BIM software	*4.240*
5	Gamil and Rahman (2019)	Middle East	Yemen	Average index	Financial restrictions	*4.671*
					Lack of BIM knowledge	*4.648*
					Improper introduction of BIM concepts	*4.632*

Note(s): MS = Mean score

Table 4.
Comparison of current study with previous studies

4.4 Preliminarily analysis

To test the appropriateness of the data on barriers of BIM in the Nigerian construction industry for further analysis, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy (MSA) and Bartlett test of sphericity (BTS) was conducted for the data on barriers to BIM as shown in Table 6.

These two tests provide the minimum standard that the data should meet to be considered adequate for further analysis. The value of the KMO can vary between 0 and 1, with 0.50 suggested as a minimum (Hair *et al.*, 2010; Field, 2013). The Bartlett test indicates whether the correlation matrix is significantly different from the identity matrix (i.e. matrix in which all of the diagonal elements are 1 and other elements are 0). The Bartlett test indicates the strength of the relationship among variables and the significant level of the Bartlett's test is a requirement for the data to be considered suitable for analysis (Field, 2013). The KMO value was 0.774 which is above 0.50 and BTS value was found to be significant at $p = 0.000$. The KMO value of 0.774 is greater than the recommended value of 0.6 (Kaiser, 1970, 1974) and Bartlett's Test of Sphericity (Bartlett, 1954) reached statistical significance, supporting the factorability of the data.

Table 7 shows the summary of Rotated Factor Matrix for the 14 barriers affecting the implementation of BIM in the Nigerian construction industry. Figure 2 shows the results of the Scree plot decision criterion which was found as most suitable to extract the number of factors in this study.

Table 5. Kruskal–Wallis one way analysis of variance (ANOVA)

Barriers*	QS n = 22		Architects n = 17		Estate surveyor n = 15		Builder n = 18		Civil engineer n = 18					
	Mean	R	Mean	R	Mean	R	Mean	R	Mean	R	K-S	df	K-W	Remark
B1	2.682	14	2.647	14	3.000	12	3.111	13	2.722	14	0.000	4	0.382	$p > 0.05$
B2	3.000	13	2.941	12	2.867	14	3.667	1	2.889	12	0.000	4	0.104	$p > 0.05$
B3	3.364	5	3.294	6	3.800	3	3.667	2	3.611	1	0.000	4	0.295	$p > 0.05$
B4	3.227	10	3.000	11	3.267	7	3.278	9	3.111	9	0.000	4	0.730	$p > 0.05$
B5	3.273	9	3.412	3	3.133	10	3.333	7	2.833	13	0.000	4	0.885	$p > 0.05$
B6	3.364	6	3.235	7	3.333	6	3.611	5	3.167	8	0.000	4	0.796	$p > 0.05$
B7	3.344	8	2.933	13	2.933	13	3.389	6	3.222	6	0.000	4	0.292	$p > 0.05$
B8	3.182	11	3.177	8	3.200	9	3.167	11	3.222	4	0.000	4	0.985	$p > 0.05$
B9	3.727	1	3.588	2	3.867	2	3.167	12	2.944	11	0.000	4	0.149	$p > 0.05$
B10	3.181	12	3.059	9	3.467	5	2.722	14	3.167	7	0.000	4	0.271	$p > 0.05$
B11	3.500	3	3.353	5	3.800	4	3.611	4	3.611	2	0.000	4	0.680	$p > 0.05$
B12	3.455	4	3.059	10	3.067	11	3.333	8	3.111	10	0.000	4	0.641	$p > 0.05$
B13	3.353	7	3.400	4	3.222	8	3.167	10	3.289	5	0.000	4	0.924	$p > 0.05$
B14	3.636	2	4.059	1	4.067	1	3.611	3	3.500	3	0.000	4	0.291	$p > 0.05$

Note(s): KW = Kruskal–Wallis; K-S = Kolmogorov–Smirnov, p-value; remark $^{a}p = 0.05$ retain the null hypothesis; $p = 0.05$ reject the null hypothesis; b. grouping variable: what is your professional background? *See Table 3 for full listing of barriers; QS = Quantity surveyor

Factor analysis was performed following Principal Component Solution with a Varimax Rotation with Kaiser Normalization (Kaiser, 1958). The data fed into Factor analysis consisted of the data obtained from respondents (90). Four components were extracted which accounted for 60.686% of the total variance from the 14 variables. These component factors were further rotated by Varimax solution. Principal Component Analysis (PCA) was the method of extraction used and rotation converged in 6 iterations. The discussion of the result was based on the Varimax rotated factor matrix. For the purpose of discussing the result of factor matrix the factor loading of 0.50 or above are significant.

4.5 Construct validity

In order to ascertain the construct validity of factors, the unifactorial determination method was used. Such an approach has been previously employed in studies such as Ghosh and Jintanapakanont (2004), and Yusof and Aspinwall (2000). Accordingly, through this method, each factor is extracted and considered as a single construct for another factor analysis running. The unifactoriality is achieved if the average variance explained value exceeds the threshold of 0.5 (Ghosh and Jintanapakanont, 2004). Meanwhile, within this method, the KMO test was also conducted for each extracted factor to assess the appropriateness of the sample. The results of these tests are shown in Table 8.

Kaiser-meyer-olkin measure of sampling adequacy		0.774
Bartlett's test of Sphericity	Approx. Chi-Square	377.945
	df	91
	Sig	0.000

Table 6.
KMO and Bartlett's test for barriers to BIM implementation

Barriers	Code	Component 1	2	3	4
Technology and business–related barrier					
Software availability issues	B6	*0.741*			
Inadequate contractual coordination	B12	*0.735*			
Data and intellectual property issues	B2	*0.690*			
Technological availability issues	B4	*0.507*			
Training and people–related barrier					
Lack of training and skills	B9		*0.786*		
Interoperability issues	B1		*0.597*		
Reluctance of other stakeholders	B10		*0.594*		
Cost and standards – related barrier					
Cost of data and information sharing	B8			*0.844*	
Business and cultural changes	B7			*0.761*	
Lack of specified standards	B5			*0.599*	
Process and economic-related barrier					
High cost of implementation	B3				*0.770*
Few studies available on BIM and lack of knowledge	B14				*0.651*
Inexistence or inadequate government policies	B11				*0.554*
Lack of demand for use and acceptance of BIM	B13				*0.507*

Note(s): Extraction Method: Principal Component Analysis; Rotation Method: Varimax with Kaiser Normalization; a. Rotation converged in 6 iterations

Table 7.
Rotated component matrix for the barriers to BIM implementation

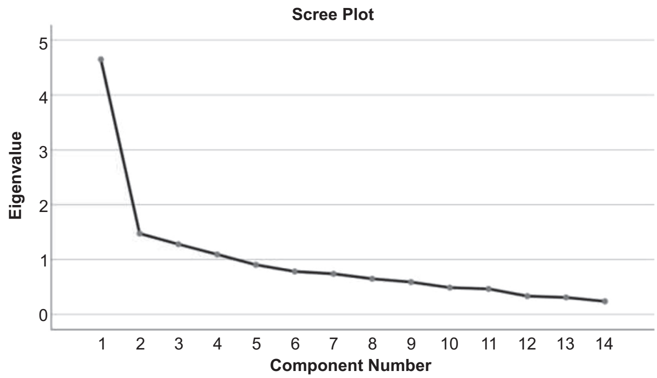

Figure 2. The scree plot showing extracted factors on 14 identified barriers to BIM implementation

Factor	Factor interpretation	Cronbach α (reliability)	Variance explained (%) (unifactorial)	KMO (unifactorial)
1	Technology and business-related barrier	0.760	33.204	0.761
2	Training and people-related barrier	0.636	10.533	0.622
3	Costs and standards-related barrier	0.716	9.138	0.603
4	Process and economic-related barrier	0.639	7.811	0.700

Table 8. Unifactorial test with the internal consistency and KMO index of principal factors

As shown in Table 8, the "technology and business-related barrier" ($\alpha = 0.760$; KMO $= 0.761$) has the strongest internal consistency, followed by Costs and standards-related barrier ($\alpha = 0.716$; KMO $= 0.603$), Process and economic-related barrier ($\alpha = 0.639$; KMO $= 0.700$), and Training and people-related barrier ($\alpha = 0.636$; KMO $= 0.622$).

4.6 Component 1: technology and business–related barrier

Despite BIM being acknowledged as a technology-enabled process, the majority of failures of BIM implementation, particularly within the developing economies context, can often be traced to technological related barriers and challenges (Enegbuma *et al.*, 2014; Raouf and Al-Ghamdi, 2019: Ma *et al.*, 2020), underpinned by business related barriers (Vass and Gustavsson, 2017; Musa *et al.*, 2019; Vidalakis *et al.*, 2020). This principal component accounts for 17.536% of the total variance of BIM barriers. This component is composed of the following four attributes: "software availability issues", "inadequate contractual coordination", "data and intellectual property issues", and "technological availability issues" with factor loadings of 0.741, 0.735, 0.690 and 0.507 respectively. The high cost (hence availability) associated with the variable of *technological availability issues* has been attributed to as one of the major challenges or barriers to BIM implementation not in in Nigeria (Saka and Chan, 2019a), but other developing countries such as China (*Ma et al.*, 2020); and Malaysia (Enegbuma *et al.*, 2014). For instance, the study by (Saka and Chan, 2019a) described BIM as technologically oriented process, thus bringing to the fore the importance around the issues of software and technological availability. Legal issues also affect BIM implementation (Bosch-Sijtsema *et al.*, 2017). Likewise, the need of eradication of the "interoperability between software programs" and "data ownership issues" as a precursor to BIM implementation are acknowledged in literature (Park and Kim, 2017). Additionally, "incorporation of BIM into the contractual relationship of the parties involved; interoperability between various programs; Intellectual Property (IP) rights and sharing of copyright data and reliance on data/software" are among the business and legal barriers to BIM implementation (Eadie *et al.*, 2015). Similarly, "absence of contractual requirement for BIM implementation", thus leading to inadequate contractual coordination is acknowledged as hindering BIM implementation (Ahmed *et al.*, 2014) Hence, this component may be renamed as *"Technology and business– related barrier"*. This component corroborates the findings of Ibrahim and Bashir (2012); and Akerele and Etiene (2016) where it was revealed that there is no government support on the adoption of BIM in the execution of construction projects, private clients are ignorant of it, and the professional bodies relevant in the construction industry have not taken steps for the training and retraining of its members on its use and application. Azhar *et al.* (2012) also stated that there are no standard protocols available for BIM models, as such; most firms adopt their own standards which creates inconsistencies and inaccuracies in BIM models. Some of the technological and business related barrier, whilst similar with the technological variables as identified by Saka and Chan (2019a), the business component is new, and does not conflict with earlier findings. The business requirement for AEC varies across different countries, and solutions to the barriers as identified would have to be country specific, and given Nigerian dominance within the Western African AEC industry (Saka and Chan, 2019a), warrants further investigation around BIM barriers.

4.7 Component 2: training and people-related barrier

Whilst not all constructional professionals might be expected to be technological savvy, BIM nevertheless is acknowledged as a process that needs people to function; hence the training of the people is necessary. However, studies such as Saka and Chan (2019a) have shown that people and process related challenges are the most prominent facing the AEC within the developing countries, and in particular training related. This principal component accounts for 14.980% of the total variance of BIM barriers. This component is composed of four attributes viz. "*lack of training and skills*", "*interoperability issues*", "*reluctance of other stakeholders*", and "*technological availability issues*". It is observed that most of the factors are related to education and technology issues. Thus, lack of training and skills (0.786) coupled with interoperability issues (0.597) and Reluctance of other stakeholders (0.599). Akdag and Maqsood (2019) findings revealed that academic syllabus of Pakistan universities in terms of built environment courses lacks thorough BIM education, it is more common for civil engineering departments rather than architecture. The low levels of education, training and skill among the workforce have been identified among the most prominent features of construction in developing countries affecting productivity (Kazaz and Ulubeyli, 2007). Most importantly, the lack of collaboration knowledge, skills and abilities led to insufficient understanding of the BIM process, and hence interoperability issues (Oraee *et al.*, 2019). More so, capabilities and skills in BIM technology are acknowledged among the strategies for enhancing BIM implementation (Ma *et al.*, 2020).

Similarly, in Iran which is a developing country like Nigeria, Marefat *et al.* (2019) identified lack of well-trained personnel among the factors that lead to failure in the adoption of BIM. The issues of "lack of understanding about BIM", and "education and training costs" also affect BIM implementation in developed countries (Newton and Chileshe, 2012), and "lack of demand and interest by stakeholders' contributes to low uptake of BIM (Tse *et al.*, 2005; Chan *et al.*, 2019). Therefore, lack of awareness of such technology as BIM also makes stakeholders of the construction industry reluctant. Studies have further shown that there is a significant association between the awareness of values of BIM and the practices related with BIM in SMEs (Rodgers *et al.*, 2015). This lack of awareness and interoperability issues has negative impact on construction projects. Hence, this component may be renamed as "Training and people-related barrier." This component aligns with previous finding on BIM implementation in both developed and developing economies (Tse *et al.*, 2005; Ezeokoli *et al.*, 2016; Hosseini *et al.*, 2016; Oraee *et al.*, 2019; Saka and Chan, 2019a; Marefat *et al.*, 2019). For instance, the studies by Ezeokoli *et al.* (2016) and Oraee *et al.* (2019) highlighted the significance or criticality of these barriers towards BIM adoption, especially the need for education and training program for project stakeholders in the construction industry. Saka and Chan (2019a) attributed the "lack of awareness" and "lack of training" to people and process related barriers. Ayinla and Adamu (2018) also revealed that costs associated with training and purchasing software licenses are usually very high, couple with the fact that many versions are released frequently. At the long run, these leads to constraint of lower cash flow for SMEs. Recent studies such as Babatunde *et al.* (2020b) also identified "cost of BIM software and training' as part of the "Cost of BIM software and training" factor. On the basis of the above findings, the study recommends that, due to the higher costs of data and information sharing, the Government provides financial assistance (i.e. loans) to the Nigerian AEC firms for procuring the BIM software.

4.8 Component 3: cost and standards – related barrier

In developing countries such as China, the absence of standards and domestic-oriented tools are acknowledged as the biggest hindrances to the practical application of BIM in China's prefabricated construction (Tan *et al.*, 2019); and Hong Kong (Chan *et al.*, 2019c). Likewise, in sub-Saharan Africa, BIM implementation is affected by lack of standardized guidelines and framework. This principal component accounts for 14.966% of the total variance of BIM barriers. This component is composed of three attributes viz. "cost of data and information sharing", "software availability issues", and "technological availability issues". Most of the identified factors in this component are associated with cost. Thus, financial resources play a vital role in the implementation of BIM as it covers the cost of data and information sharing (0.844), business and cultural changes (0.761), and lack of specified standards (0.599). The lack of BIM standards affects the implementation of BIM (Saka and Chan, 2019a). Ayinla and Adamu (2018) tagged cost as a major constraint to BIM adoption while other studies such as Eadie *et al.* (2015) have identified "cost of BIM process, investment in software, hardware and training" among the barriers to BIM. As illustrated in Table 1, lacks standards as a barrier to BIM implementation are well documented in literature (Bin Zakaria *et al.*, 2013; Chan, 2014). Whilst the issue of high cost of BIM implementation has been attributed to the prevalence of small and medium enterprises (SMEs) within the African AEC industry (Saka and Chan, 2019a), it still remains a major barrier to BIM implementation both in developed and developing countries (Abubakar *et al.*, 2014; Gibbs *et al.*, 2015; Rogers *et al.*, 2015). For instance, Gibbs *et al.* (2015) identified cost of BIM process, investment in software, hardware and training among the financial related barriers to BIM implementation. Hence, this component may be renamed as *"cost and standards- related barrier"*.

Studies such as Abubakar *et al.* (2014) and Rogers *et al.* (2015) consented unequivocally to the fact that implementation of BIM has a relatively high initial outlay, and this is in no small measure discouraging the adoption of BIM. This is as most client especially those who have no prior use of BIM on their projects see the heavy initial outlay as a turnoff not considering the immense cost savings BIM offer in the later stages of the project (Nanajakar and Gao, 2014). Likewise, the issue of cost not only affects developing economies but developed ones as well. For instance, Newton and Chileshe (2012) undertaken in Australia identified "start-up costs" among the barriers affecting the implementation of BIM particularly in SMEs.

Similarly, Georgiadou (2019) findings expressed that there is widespread of BIM awareness in the UK but financial barrier remains one of the main setbacks in acquiring digital infrastructures that will facilitate BIM adoption, especially for small- and medium-sized enterprises. Whist lack of BIM-standards has been identified amongst the challenges or barriers affecting the implementation of BIM in developing countries, this has previously been incorporated within the "Technology related" factor (Saka and Chan, 2019a). In contrast, in our study we have named this as "Costs and standards" due to the synergies between cost elements and technological issues. More so, some of the technological and business related barrier, whilst similar with the technological variables as identified by Saka and Chan (2019a), the business component is new.

4.9 Component 4: process and economic-related barrier

Building Information Modeling is often regarded as an innovative technology coupled with process and human interactions (Musa *et al.*, 2019). However, the quest for BIM implementation is often hinders by stakeholders reluctance in invest in the BIM technology due to economic reasons (Saka and Chan, 2019a). These challenges further highlight the role that the governments in developing countries have in mandating policies that support a BIM-enabling environment. Component 4 (4 items), explaining 13.204% of the total variance of BIM barriers, was termed "Process and economic-related barrier". This component is composed of four attributes namely; *"high cost of implementatio*n" (0.770), few studies available on BIM and lack of knowledge (0.651), *"inexistence or inadequate government policies"* (0.554), and "*lack of demand for use and acceptance of BIM"* (0.507). As observed by Saka and Chan (2019a), within the African continent (of which Nigeria is situated), the BIM push tend to leans towards a "bottom-up" approach in the absence of government mandate. The same study (*ibid*) identified these barriers as leading to the gap in the lack of government support and demand for BIM in most of the countries. The finding further reinforces the existence of the relationship between the two variables represented within this component namely, "*inexistence or inadequate government policies*" and "*lack of demand for use and acceptance of BIM"*. The low demand from the clients and high cost of software has also been identified as major barriers to BIM implementation in developing countries (Marefat *et al.*, 2019; Vidalakis *et al.*, 2020).

Finally, the four *attributes or variables* as represented in this component are directly or indirectly associated with the "processes / people" and "economic" factors as suggested by Saka and Chan (2019a). Limited studies on BIM also acts as barriers to BIM implementation. For instance, Tan *et al.* (2019) reported on *the lack of research about BIM* in China among the barriers to BIM in the prefabricated construction. China, like Nigeria is also a developing country (though moving towards developed status). The construction industry is undergoing a radical change as project owners are demanding for more project visibility at lower cost and better risk management; this has increased the use of new technologies in project implementations (Ogwueleka and Ikediashi, 2017; Ruya *et al.*, 2018). Finally, as noted in the literature review, Nigeria like most developing countries suffers from the lack of existing government policy or intervention effort aimed at encouraging the adoption and knowledge of BIM (Ibrahim and Bashir, 2012; Aluhofai, 2012). Therefore, this omission (lack of government policy) discourages other private investors from taking BIM adoption (hence the lack of demand for use and acceptance of BIM). These efforts are further compounded by the few studies available on BIM and lack of knowledge. These barriers consequently lead to low industry uptake due to lack of awareness (limited knowledge) and compounded by higher cost of implementation. Whilst some examples have been drawn from China, these findings as reported further highlights the significance of the process and economic related barriers to Nigeria. Drawing upon the Chileshe and Kikwasi (2014) which identified "awareness campaign" as a catalyst for increased uptake of risk management practices, the emergent implication is that there is a need of "BIM benefits awareness campaign" amongst the Nigerian stakeholders within the AEC sector for the purpose of sensitization of their members on the benefits of implementation of BIM, this leading to more BIM uptake, and increased knowledge of the adoption process.

4.10 Mathematical validity

Drawing upon the approach of Doloi *et al.* (2012), Pearson correlation was computed to examine the correlation among the variables or attributes within each of the 4 factors. The results are shown in Table 9.

As can be seen from Table 9, some the bivariate correlations were greater than 0.4 in some cases thus indicating evidence of the attributes or variables belonging to their respective factors. The higher Cronbach's alpha coefficients of the factors as illustrated in Table 8 further demonstrates the good internal consistency of the factors or sub-scales.

4.11 Four-point road map for effective implementation of BIM in the Nigeria construction industry

The study revealed a road map for effective implementation of BIM in the Nigerian construction industry. The road map is illustrated in Figure 3.

Regarding Curriculum Reforms, this will include three parties (government, National University Commission, and Professional bodies). The National University Commission

Factor 1: Technology and business–related barrier				
	B6	B12	B2	B4
B6	1			
B1	0.522	1		
B2	0.527	0.421	1	
B4	0.398	0.420	0.359	1

Factor 2: Training and people- related barrier			
	B9	B1	B10
B9	1		
B1	0.357	1	
B10	0.462	0.278	1

Factor 3: Cost and standards – related barrier			
	B8	B7	B5
B8	1		
B7	0.514	1	
B5	0.570	0.302	1

Factor 4: Process and economic – related barrier				
	B3	B14	B11	B13
B3	1			
B14	0.333	1		
B11	0.362	0.225	1	
B13	0.297	0.319	0.323	1

Table 9. Correlation matrix for the attributes

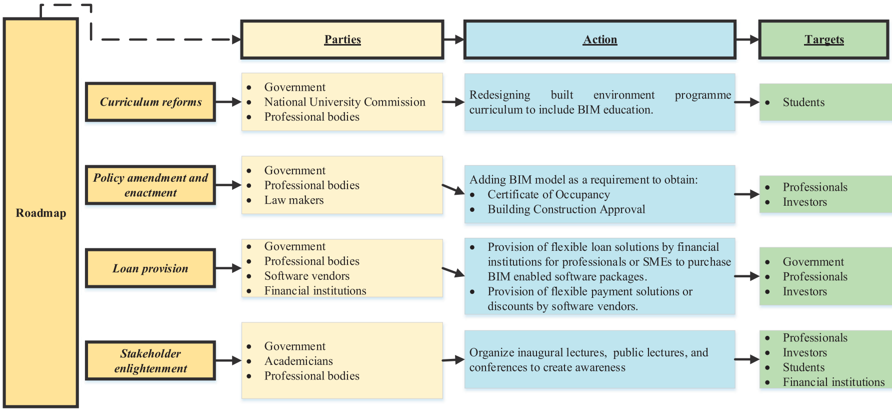

Figure 3.
Four-point roadmap for effective BIM implementation in Nigerian construction industry

(NUC) is a parastatal under the Federal Ministry of Education in Nigeria. They regulate academic program in Nigerian universities. NUC will engaged academicians in relevant fields to redesign built environment program curriculum in Nigerian universities to include BIM courses that will equip graduates with the necessary knowledge for effective BIM implementation in practice. It should be done in consultation with relevant built environment professional bodies like *Nigerian Institute of Architects* (NIA), *Nigerian Institute of Quantity Surveyors* (NIQS), *Nigerian Institute of Town Planners* (NITP), etc. and government agencies. In terms of Policy Amendment and Enactment, this will include three parties (Government, Professional bodies, and Law makers). Law makers will enact policies that will enforce the use of BIM in all levels of government and all built environment professional bodies. There is also a need for the Amendment of Certificate of Occupancy (C of O) and Building Construction Approval requirements to include BIM models. This will make all clients engage BIM experts. As regards Loan Provision, Government and relevant professional bodies should come together to discuss finance and payment solutions with financial institutions and software vendors respectively. The financial institutions will be required to provide flexible loan to professionals who are in need BIM software packages while vendors will be required to provide flexible payment solutions or discounts to Nigerian based SMEs and professionals. Lastly, Stakeholders Enlightenment is an important section of the roadmap. Government, academicians, and professional bodies should create more awareness regarding the benefits that can be derived when BIM is fully implemented into construction workflows. This will include organizing inaugural lectures, public lectures, conferences, etc.

5. Conclusions, recommendations and future research

This study has presented results of a questionnaire survey with the main aim of determining the barriers to the implementation of BIM in the Nigerian construction industry. The topmost five barriers of BIM in order of mean response and significance are: few studies available on BIM and lack of knowledge, inexistence or inadequate government policies, high cost of implementation, lack of demand for use and acceptance of BIM, and inadequate contractual coordination. This finding implies that only some of the barriers are critical to the implementation of BIM in Nigeria. (Mean score greater than 3.5).

The result of the factor analysis was able to identify the four most important components (Technology and business-related barriers; Training and people-related barriers; Cost and standards – related barriers; and Process and economic-related barriers.) that influence the implementation of BIM in the industry. These components form the key barriers that influence BIM implementation negatively in the Nigerian construction industry. The implications of the findings from the factor analysis would enable the barriers to be addressed in a comprehensive manner by tailoring the mitigations. Such an approach would also enable the understanding and estimation of the extent of relationships among variables, thus providing academia with both the theoretical constructs that underlie a particular data set.

5.1 Significant contributions and implications
The study's significant contribution is threefold: First, the main contributions of this study lies in the identification of an ordered grouped set of barriers to the implementation of BIM within the Nigerian construction industry. Secondly, as acknowledged by Brown and Dant (2008), adding new knowledge through the filling in of knowledge gaps constitutes as significant contributions to knowledge. Therefore, another significant contribution of this paper is that it sheds light and provides insights on the understanding of the barriers that inhibit the implementation of BIM within the Nigerian construction sector environment, an area previously under-researched. It also expands the efforts of studying and evaluating the barriers across the developing economies and particularly within the Western African context, a region identified as having BIM still at the germinating stage of development in Africa (Saka and Chan, 2019a).

5.2 Practical implications
The study generated a number of practical implications. Firstly, for improvement in the adoption ate of BIM; *academician*, *government* and other *construction industry stakeholders* need to embrace the concept of BIM. It is observed that there is dearth in skills and knowledgeable professionals in areas of BIM technologies in the industry, the academic curriculum for built environment courses in Nigeria environs is designed to include little component of BIM. Academicians in construction field are also encouraged to embrace the concept of BIM because they have high impact on students BIM education. Secondly, BIM if fully implemented has the potential to eliminate inefficiencies in the construction industry and pave ways for integration with other emerging technologies applicable to construction. Thirdly, it is important for Government to show utmost concern towards BIM by creating an enabling environment through amendment of policies applicable to the construction industry to favour BIM adoption. Government can as well leverage on the identified barriers to develop a plan that will be aimed at improving BIM adoption in the construction industry.

5.3 Research limitations and future directions
Despite the contribution made by this research, it is still having its flaws. In terms of geographical limitation, the research focused on a single State in Nigeria which affects its generality. Also, the sample size ($n = 90$) used was small. A suggestion for future research may consider using large population which will include many professionals from the construction industry and as well consider other developing countries of the world to improve the generality of tis research. In addition, the research concentrated solely on the information gathered from literature which makes it difficult for respondents to fully give their own perception. Future researches can adopt qualitative methods such as Delphi technique, focus group, and other qualitative methods so as to give respondents more ability to make their input concerning the implementation barriers of BIM as well as validate the barriers thus identified. Furthermore, drawing upon Yalegama *et al.* (2016), as the grouping of the barriers is based on the exploratory factor analysis, and its interpretations are only post hoc and

subject to considerable error, more studies to cross-check the accuracy of the extracted barriers to BIM are needed. Research could also be conducted on the barriers influencing BIM implementation using advanced research methods.

5.4 Recommendation

Based on the findings, we suggest a number of recommendations as follows:

(1) *Curriculum reforms*: The curriculum of built environment courses in Nigeria tertiary institutions should be reformed to accommodate BIM education with the focus to create stream of BIM oriented professionals;

(2) *Policy amendment and enactment*: The Government should tailor or create construction policies to facilitate the use of BIM on every construction project just like the United Kingdom and other developed countries. These policies will encourage the implementation of BIM in Nigeria;

(3) *Loan provision*: The Government could create a loan system that will assist construction organizations in procuring BIM infrastructures due to its high cost;

(4) *Stakeholder enlightenment*: Stakeholders of the construction industry should be enlightened on the benefits that could be derived from BIM adoption. Such (enlightenment) could contribute towards improving the acceptance levels of BIM in the industry.

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