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An Analysis of Building Information Modeling (BIM) Usage in Nigerian Construction Industry

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Abstract

The global construction industry is in rising demand for Building Information Modeling (BIM) components in new construction projects. Although there has been significant increase in industry-wide acceptance of BIM, and in spite of its benefits, it is still not a standard practice in Nigerian Construction Industry (NCI). This research aimed at exploring the use of BIM among architects in Nigeria. A survey that investigated BIM awareness and usage, BIM software used in projects, activities executed using BIM and barriers to BIM usage was distributed to architects practicing in NCI. Responses were collected using questionnaires and data analyzed through descriptive and statistical tests. The survey results indicated a low usage of BIM in construction projects despite architects showing fair awareness of BIM. The result also revealed BIM was mostly used for architectural detailed design, 3D visualization, architectural modelling, scheduling and construction documents coordination. Lack of clients demand, poor leadership and organization towards digital innovation and cost of training were the three top obstacles to BIM implementation. The research contributes to the existing body of knowledge by providing insight into BIM usage in Nigeria. It is expected that this knowledge could be useful for BIM implementation and tackle barriers to BIM adoption in the Nigerian construction industry.

Keywords: BIM usage, architects; construction industry; Nigeria

1. Introduction

In recent time, there had been a growing interest in Building Information Modeling (BIM) as an evolving collaboration and digital transformation tools in the architecture, engineering and construction (AEC) industry to reduce costs, increase quality and manage resources efficiently. Theoretically, there is consensus in the literature that BIM has the potential to revolutionize project delivery process by enhancing design and engineering creativity and ensure inter-dependency of the design, construction and operation of the built environment. Kubba (2012) described BIM as a lifesaver due to its ability to identify and rectify errors at early design stage and accurately break down schedule of construction project into detailed tasks.

As the construction industry started to embrace the concept of BIM, Anton and Diaz (2014) suggested that the concepts should be implemented in the early stage of the building design process, as it can impact a project effectively. Zhao et al. (2021) reinforced this and noted that for a building to be energy efficient, BIM as an enabling software can be used to simulate and predict the energy performance. Ku and Taiebat (2011) found that the BIM technology has been welcomed by professionals in several countries and used to reduce cost, time, and enhance quality as well as environmental sustainability. Popov et al. (2010) suggest that BIM provides a platform that facilitates the creation and sharing of information relevant for design, construction and maintenance of buildings over their entire lifecycle. BIM is capable of supporting project integration into a collaborative process, to promote increase efficiency and reduce conflict in project delivery system (Grilo and Jardim-Goncalves, 2010). The completeness of the information enables better lifecycle management and sustainable building design (Azhar et al., 2011). With the integrated information model, visualization of construction process and design details is easier which facilitates analysis of alternative solutions (Popov et al. 2010) and identification of potential conflicts (Grilo and Jardim-Goncalves, 2010).

Furthermore, BIM reduces the duration and cost of a project, improves maintenance management and increases the value of the building (Barlish and Sullivan, 2012). Tomek and Matejka (2014) pointed out that BIM has impact on both external and internal risks in construction industry. This is important according to what Rezakhani (2012) says that due to unique properties of construction operations, many risk factors are involved in construction project. BIM also improves communication between the different project parties (Hatem et al., 2012). On the other hand, BIM as a new phenomenon seeks to renew the practices of the construction industry, so it is subject to several barriers facing its application despite its outstanding capabilities (Kekana et al., 2014).

Despite the increased global interest in BIM development, the level of adoption in Nigeria construction industry is still very low (Akadiri and Omisakin, 2020; Saka et al. 2020) Ugochukwu et al. (2015) described the Nigerian construction industry as "notoriously conservative and slow to change", despite been faced with so many challenges. The authors went further supporting this statement nothing that the traditional procurement and building delivery methods have largely remained the same for decades. A comprehensive review of literature published from 2000 to 2022 showed an insufficient attention from researchers, leading to a very few BIM publications in the context of the Nigerian construction industry. Babatunde et al. (2020) examined BIM uptake among contracting firms in Nigeria. Onungwa et al. (2017) explore BIM as a tool for construction management in Nigeria. Whereas, the barriers to building information modeling (BIM) implementation within the Nigerian construction industry were identified by Olanrewaju et al. (2020). This is in addition to other studies (Muhammad et al (2018); Anifowose et al. (2018); Amuda et al (2018);Olapade and Ekemode (2018); Ezeokoli et al. (2016) which investigated the awareness, adoption and impact of BIM in the Nigerian construction industry. However, these studies failed to recognize the uniqueness of the different professions and the need for developing specific BIM uses in different project phases by different disciplines.

In other words, the literature review indicated a scarcity of literature on BIM use for building projects in Nigeria with a focus on architects who are responsible for the implementation of BIM at the early stage of the construction process. It also showed that there is limited knowledge regarding the existing use of BIM within the construction industry, which motivated the conduct of this research. Against this background, the goal of this research is to explore the perspectives of architects in the Nigeria construction industry towards BIM adoption. More importantly, this research addressed the following research questions.

a) What is the level of awareness of BIM use among building stakeholders?
b) What are the BIM software packages use for building projects
c) What are the building activities executed using BIM?
d) What are the obstacles of/to BIM implementation in projects?

2. Research Methods

The purpose of this research is to understand the use of BIM by architects in building projects. The study reviews extant literature on BIM technology and its use in Nigeria. A quantitative research method through structured questionnaire was employed for data collection and analysis. The sample frame consists of practicing architects in registered Architectural, Engineering and Construction (AEC) firms in Nigeria. An invitation to participate in a web-based QuestionPro survey was e-mailed to architects drawn from a database of around 1,500 AEC practices registered in Nigeria. A total of 540 questionnaires were mailed out to participants for completion, out of which 48 respondents indicated the use of one form of BIM software or another and are therefore processed for this research. The survey responses were analyzed using the SAS 9.0 statistical software package. The generated data were analyzed through descriptive statistics (in percentages) and presented in charts and graphs. The participants were asked to indicate the frequency of use of 22 different BIM software packages using 3-Point Likert type scale of "1" for *Never*, "2" for *occasionally*, and "3" for *Frequently.* Rating for usage of BIM software was based on a 5-Point Likert type scale ranging from "1" for *Strongly Disagree* to "5" for *Strongly Agree.* In order to identify the relative importance of the obstacles to BIM adoption, ranking analysis was performed using relative index analysis . The following formula is used to determine the relative index (Akadiri, 2015):

$$RI = \sum \mathrm{w}/\mathrm{A} \times \mathrm{N} \qquad (1)$$

where w is the weighting as assigned by each respondent on a scale of one to five with one implying the least and five the highest. A is the highest weight (i.e. 5 in this case) and N is the total number of the sample. Following the work of Chen et al. (2010) and Akadiri (2015), five important levels are transformed from RI values: high (H) ($0.8 \le RI \le 1$), high-medium (H–M) ($0.6 \le RI < 0.8$), medium (M) ($0.4 \le RI < 0.6$), medium-low (M-L) ($0.2 \le RI < 0.4$) and low (L) ($0 \le RI < 0.2$).

3. Results and discussion

The characteristics of the respondents were categorized using the area of specialization, type, age and size of organization and work experience in Table 1. Experience of respondents was highly impressive as 43.7 per cent have over 20 years' experience working in the building and construction industry, 18.8 per cent has industry experience ranging between 11 and 20 years, while 37.5 per cent have at least ten years or less. As for the size of organization, 66.6 per cent work in small-to-medium size organizations, with a small proportion 14.6 per cent working in large organizations with over 250 staff. The result also shows that 54.2 per cent work in an architectural/design office while most of the respondent's area of project specialization is residential and institutional buildings at 43.7 and 39.6 per cent respectively. From the above it can be concluded that respondents played important role in their organizations and are very experienced. These characteristics make their view on the relevance of survey important and can be sufficiently relied upon with confidence.

3.1 Level of awareness and BIM usage

The survey participants were asked to identify the level of awareness of BIM. From the result in Figure 1, 43.8 percent of respondents stated that they are aware of BIM and have either used or still using the technology. A further probe to know the level of usage among the users shows that only 9.2 percent are actively using BIM as seen in figure 2.

Table 1. Demography of experts

Variable	Number	Percentage (%)
Work experience		
<5 years	4	8.3
6-10 years	14	29.2
11-20 years	9	18.8
>20 years	21	43.7
Size of organization (by staff)		
<10 staff	20	41.6
11-50 staff	12	25.0
51-249 staff	9	18.8
250-500 staff	4	8.3
>500 staff	3	6.3
Age of organisation (in years)		
<5 years	4	8.3
6-10 years	6	12.5
11-20 years	16	33.3
21-30 years	13	27.1
>30 years	9	18.8
Type of organization		
Architecture/design	26	54.2
Civil/structural engineers	14	29.2
Building Contractors	8	16.6
Area of project specialism		
Commercial	7	14.6
Residential	21	43.7
Institutional	19	39.6
Industrial	1	2.1

This however indicate that awareness does not necessarily reflect active usage. This findings collaborate previous studies by Dare-Abel et al. (2014) and Hamma-Adama et al. (2018) which report that the usage of BIM is low among architects who are aware of it in Nigeria construction Industry. An explanation for the low-usage could be that they haven't handled project in which BIM was part of the project criteria and are rather ignorant about the importance and benefits of its usage.

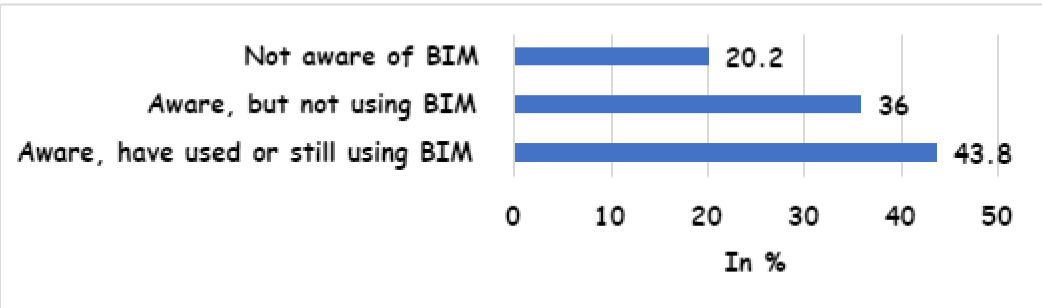

Figure 1: BIM level of awareness

Whilst BIM has been receiving attention globally as its realization has been identified as the basis for the generation of users satisfaction, respondents were asked to evaluate BIM software user-friendliness based on 5 criteria of comfort, operability, task accomplishment, flexibility and productivity listed in Table 2.The criteria and the variables were adapted from the work of Park et al. (2022).

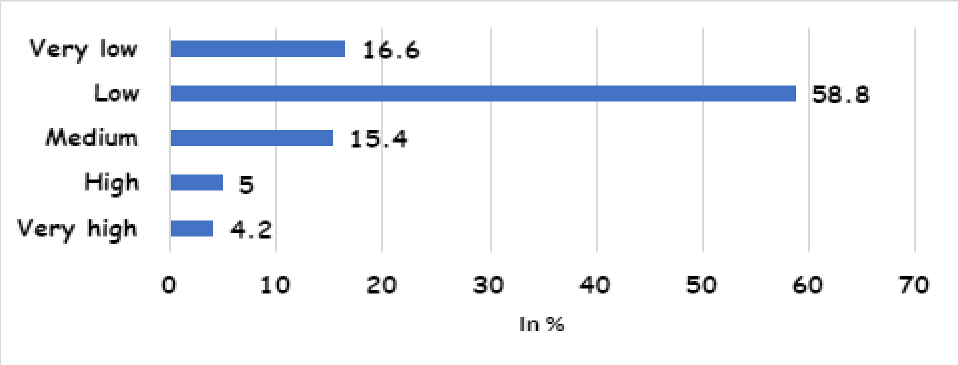

Figure 2: BIM level of Usage

Table 2. BIM users satisfaction

Criteria	Variables	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean score
		n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Comfort	Pleasant, easy-to-navigate user interface(toolbar, screen composition, etc.)	3 (6.3)	2 (4.2)	5 (10.4)	15 (31.2)	23 (47.9)	4.10
	It is easy to use in terms of parametric functions and components	1 (2.1)	5 (10.4)	5 (10.4)	17 (35.4)	20 (41.7)	4.04
	Easy to install	2 (4.2)	3 (6.3)	0 (0.0)	18 (37.5)	25 (52.0)	4.27
	The software workflow is good	4 (8.3	5 (10.4)	2 (4.2	16 (33.3	21 (43.8)	3.94
Operability	Fast operation time and synchronization are possible	5 (10.4)	7 (14.6)	3 (6.3)	17 (35.4)	16 (33.3)	3.67
	I am satisfied with functions such as measuring environmental impacts	9 (18.8)	10 (20.8)	4 (8.3)	14 (29.1)	11 (23.0)	3.17
	It has sufficient functions to respond to the standards of the ordering system and government permission	7 (14.6)	14 (29.1)	2 (4.2)	13 (27.1)	12 (25.0)	3.19
Task accomplishment	The software has enough tools to use in the early stages of design	8 (16.7)	12 (25.0)	1 (2.1)	12 (25.0)	15 (31.2)	3.29
	The software has enough features to support modeling tasks	8 (16.7)	8 (16.7)	3 (6.3)	15 (31.2)	14 (29.1)	3.40
	The software support community, including tutorials, is sufficient	11 (22.9)	9 (18.8)	7 (14.6)	11 (22.9)	10 (20.8)	3.00
Flexibility	Interoperability with other software and systems is good	4 (8.3)	6 (12.5)	2 (4.2)	17 (35.4)	19 (39.6)	3.85
	The software has a working environment that enables efficient collaboration	2 (4.2)	3 (6.3)	4 (8.3)	15 (31.2)	24 (50.0)	4.17
	I am satisfied with Autodesk Cloud services	5 (10.4)	6 (12.5)	4 (8.3)	16 (33.4	17 (35.4)	3.71
	Easy to update and troubleshoot	1 (2.1)	5 (10.4)	5 (10.4)	17 (35.4)	20 (41.7)	4.04
Productivity	It reduces simple and repetitive tasks due to libraries, etc.	6 (12.5)	7 (14.6)	3 (6.3)	18 (37.5)	14 (29.1)	3.56
	The paperwork time is reduced by easily deriving the information required for the project	1 (2.1)	4 (8.3)	2 (4.2)	17 (35.4)	24 (50.0)	4.23
	The software improves the productivity of work	3 (6.3)	3 (6.3)	5 (10.4)	14 (29.1	23(47.9)	4.06

With a mean score ranging from 4.04 to 4.27, ease of installation of BIM software, the ability of the technology to reduce paperwork time by easily deriving the information required for the project a working environment that enables efficient collaboration, pleasant, easy-to-navigate user interface, improved work productivity, ease of use of parametric functions and components and ability to update and troubleshoot were the top satisfaction of BIM software. These findings are important as it emphasizes user's emotional and cognitive evaluation of the entire BIM experience and could provide an excellent framework for the management of BIM from the user's perspective, thereby help to stimulate user's acceptance of BIM in the Nigeria construction industry in future.

3.2 BIM Software usage by the Respondents

In terms of the BIM software usage, the large majority of the architects at 75.2% responded that they always use Revit™ Architecture out of the 22 BIM software investigated (Table 3). This is not a surprise because Autodesk Revit Architecture was specifically designed and developed to meet the needs of architects. As anticipated, this was closely followed by AUTOCAD and Google Sketchup at 62.4% and 43.1 % respectively. These three software are particularly used as they allow architects to design, document, visualize, and deliver architecture, engineering, and construction projects more efficiently.

Table 3 Frequency of use of BIM software

BIM software	Never	Sometimes	Always
	n(%)	n(%)	n(%)
Blender	41 (85.4)	4 (8.3)	3 (6.3)
Cattia	45 (93.7)	1(2.1)	2 (4.2)
SolidWorks	46 (95.8)	2 (4.2)	0 (0.0)
Bricscad	46(95.8)	1 (2.1)	1 (2.1)
Autodesk Revit	3 (6.3)	10 (20.8)	35 (72.9)
Ecotect	41 (85.4)	5 (10.4)	2 (4.2)
Digital Project	40 (83.3)	7 (14.6)	1 (2.1)
Allplan Architecture	44 (91.6)	3 (6.3)	1 (2.1)
Edificius	35 (72.9)	9 (18.8)	4 (8.3)
Google Sketchup	6 (12.5)	13 (27.1)	29 (60.4)
3Ds Max	12 (25.0)	11 (22.9)	25 (52.1)
Lightworks	44 (91.6)	2 (4.2)	2 (4.2)
Revizto	24(50.0)	15 (31.2)	9 (18.8)
Rhinoceros 3D	28 (58.3	11 (22.9)	9 (18.8)
Caddie	18 (37.5)	28 (58.3	2 (4.2)
AutoCAD	2 (4.2)	13 (27.1)	33 (68.7)
Vectorworks Architect	18 (37.5)	22 (45.83)	8(16.7)
Lumion	11 (22.9)	9 (18.8)	28 (58.3)
Infurnia	43 (89.6)	5 (10.4)	0 (0.0)
DataCAD	35 (72.9)	8 (16.7)	5 (10.4)
ArchiCAD	8 (16.7)	12 (25.0)	28 (58.3)
Houdini	47 (97.9)	1 (2.1)	0 (0.0)

In a typical construction projects, different activities are carried out by architects aided with use of BIM software. These activities are listed in Table 4 based on the perceived duties of architects from the design to construction stage. The survey participants were asked to rank relevant task done by BIM.The most commonly used BIM functions include schematic design and presentation of drawings, 3D visualization, architectural modelling, architectural details and Scheduling. Energy analysis, solar analysis, structural analysis and lighting analysis make up the least activities BIM is used for in Nigeria. As expected these are duties directly at the realm of the architectural profession and as such the focus is in using BIM to improve the quality and accelerate the design process.

Table 4: Ranking of Relevant Tasks done by BIM

Tasks	Response	
	Yes	No
	n(%)	n(%)
Schematic design and presentation of drawings	47 (97.9)	1 (2.1)
Architectural modelling	45 (93.7)	3(6.3)
3D visualization	46 (95.8)	2 (4.2)
Construction documents coordination	41 (85.4)	7 (14.6)
Specification writing	32 (66.7)	16 (33.3)
Scheduling	43 (89.6)	5 (10.4)
Clash detection	40 (83.3)	8 (16.7)
Architectural details	46 (95.8)	2 (4.2)
Virtual reality	26 (54.2)	22 (45.8)
Quantity Take-off	36 (75.0)	12 (25.0)
Facilities management/building renovation	39 (81.2)	9 (18.8)
Construction logistics and procurement	36 (75.0)	12 (25.0)
Lighting analysis	11 (22.9)	37 (77.1)
Energy analysis	9 (18.8)	39 (75.0)
Solar analysis	8 (16.7)	40 (83.3)
Structural analysis	10 (20.8)	38 (79.2)
Indoor human comfort analysis	26 (54.2)	22 (45.8)

3.3 Barriers of BIM adoption

Relative index analysis was used to rank the criteria according to their relative importance. Table 5 show the ranking results for each criteria category (e.g. technological) by using the relative index analysis in Equation (1). Based on these ranking results, 12 criteria were highlighted to have "high" importance levels in evaluating building material with an RI value between 0.808 and 0.898. These twelve criteria are " Lack of awareness (O4)", Lack of trained professionals (O6)", Cost of BIM software (O9)", Lack of clients demand (O1)", Lack of empowerment and support to digital innovation (O7)", Poor leadership and organization towards digital innovation (O8)", Unavailability of new digital tools (T4)", Slow speed of computers in processing and drawing extraction (T3)", Poor power supply (T8)", Limited availability of digital tools to deliver digital innovations (T9)", Inflexible building code (LR1)", Submission of drawings is still hard to copy (LR4)". "Lack of awareness" was ranked as the first priority in the organizational category with an RI value of 0.898, and it was also the highest among all criteria and was highlighted at "High" importance level.

Table 5.Obstacles affecting adoption of BIM

Source	Laws and Regulations	Organizational criteria	Technological criteria
Literature review, existing and focus of construction stakeholders	LR 1: Inflexible building codes LR 4: Submission of drawings is still hard copy LR 2: Submission of drawings doesn't use digital copy from digital innovations LR 3: High standard of digital modelling and procedure established by government for drawing submission.	O8: Poor leadership and organizational attitude towards digital innovation O7: Lack of empowerment and support to digital innovation O6: Lack of trained professionals to manage BIM innovation O4: Lack of awareness O1: Lack of client's demand O9: Cost of BIM software O11: Cost of training O2: Lack of assured return on investment O3: High equipment (computer) maintenance cost O5: Fear of work changes O10: Lack of psychological assurance	T7: Lack of training for technology T1: Lack of interest for the knowledge of digital technology, T6: Lack of adequate ICT infrastructure T5: Insufficient skills on the technology T4: Unavailability of new digital tools T3: Slow speed of computers in processing and drawing extraction T8: Poor power supply T9: Limited availability of digital tools to deliver digital innovation T2: Slow data processing of 3d models

Table 3. Rank of criteria affecting BIM adoption

Criteria	Valid percentage of score of (%)					Relative index	Ranking by category	Overall ranking	Importance level
	1	2	3	4	5				
Organizational criteria									
O4: Lack of awareness	0.0	0.0	10.1	30.3	56.9	0.898	1	1	H
O6: Lack of trained professionals to manage BIM innovation	0.0	0.0	3.3	47.3	49.5	0.892	2	2	H
O9:Cost of BIM software	0.0	0.0	3.2	50.4	46.2	0.886	3	3	H
O1: Lack of clients demand	0.0	0.0	4.4	50.5	45.1	0.881	4	4	H
O7: Lack of empowerment and support to digital innovation	4.4	1.1	13.2	29.7	51.6	0.846	5	7	H
O8: Poor leadership and organization towards digital innovation	1.1	1.1	18.0	46.1	33.7	0.820	6	10	H
O11:Cost of training	1.1	9.9	28.6	47.3	13.2	0.723	7	19	M-H
O2: Lack of assured return on investment	1.1	10.1	36.0	34.8	18.0	0.717	8	20	M-H
O3: High equipment (computer) maintenance cost	4.4	8.8	35.2	39.6	12.1	0.692	9	21	M-H
O5: Fear of work changes	4.4	15.4	31.9	37.4	11.0	0.670	10	22	M-H
O10: Lack of psychological assurance	5.5	19.8	45.1	20.9	8.8	0.615	11	24	M-H
Technological criteria									
T7: Lack of training for technology	3.3	8.8	19.8	39.6	28.6	0.763	7	15	M-H
T1: Lack of interest for the knowledge of digital technology	3.3	2.2	22.2	38.9	33.3	0.793	5	13	M-H
T6: Lack of adequate ICT infrastructure	3.3	7.7	29.7	39.6	19.8	0.729	9	18	M-H
T5: Insufficient skills on BIM technology	1.1	7.7	29.7	38.5	23.1	0.749	8	17	M-H
T4: Unavailability of new digital tools	0.0	0.0	13.2	44.0	42.9	0.859	1	5	H
T3: Slow speed of computers in processing and drawing extraction	0.0	0.0	9.9	53.8	36.3	0.853	2	6	H
T8: Poor power supply	0.0	0.0	12.1	56.0	31.9	0.839	3	8	H
T9: Limited availability of digital tools to deliver digital innovations	1.1	3.4	15.9	40.9	38.6	0.825	4	9	H
T2: Slow data processing of 3D models	1.1	1.1	28.6	48.4	20.9	0.774	6	14	M-H
Laws and Regulations criteria									
LR1: Inflexible building code	0.0	5.5	14.3	49.5	30.8	0.810	1	11	H
LR4: Submission of drawings is still hard copy	1.1	0.0	22.0	47.3	29.7	0.808	2	12	H
LR2: Submission of drawings doesn't use digital copy from digital innovations	3.3	5.5	23.1	48.4	19.8	0.752	3	16	M-H
LR3: High standard of digital modelling and procedure established by government for drawing submission.	5.5	16.5	39.6	29.7	8.8	0.639	4	23	M-H

A total of 12 criteria, consisting of 5 organizational criteria, 5 technological criteria, and 2 laws and regulations criteria, were recorded to have “High– Medium” importance levels. Although these 12 criteria were in the same importance level category, the laws and regulations criteria (average RI=0.695) were less important compared to the organizational criteria (average RI=0.774) and technological criteria (average RI=0.716). An interesting observation is that none of the criteria fall under the medium and other lower importance level. This clearly shows how important the criteria are to building professionals as factors affecting the adoption of BIM. All criteria were rated with “High” or “High–Medium” importance levels.

4. Conclusions

This study investigated the use of BIM by architects in Nigeria Construction Industry. The objectives were to determine perceptions of the design professionals about BIM adoption and implementation on construction projects. The result of an online questionnaire survey sent to 540 architects indicated a high awareness level but low BIM usage on projects as only 48 respondents have used one form of BIM software or another. The majority of those respondents who did not use BIM would be interested in implementing BIM in the future with only 5% that indicated having no interest in using BIM.

The result also revealed that the major BIM applications are architectural detailed design, 3D visualization, architectural modelling, scheduling and construction documents coordination. These were done mainly using CAAD BIM software such as Autodesk Revit Architecture, AutoCAD and Google sketch up. As expected, the major BIM applications and software usage were based on the discipline’s scope of work, which is firstly to prepare architectural drawings. This also implies that there is a limited use of BIM software for analyses when compared to their use for architectural design and drafting, hence, capacity building is needed in the area of optimization of the various BIM tools in architectural practice to increase productivity, efficiency, and quality. Regarding the Specific obstacles that prevent the frequent usage of BIM use on construction projects, the majority of respondents indicated lack of clients demand, poor leadership and organization towards digital innovation and cost of training as the three top obstacles to BIM usage.

Since these are derived from the survey through expert opinion, they symbolize the obstacles that affect the adoption of BIM technology by architects in Nigeria Construction Industry. Consideration of these obstacles will go a long way in enhancing BIM’s uptake through vigorous campaigns, sensitization, and training of architects on the use of BIM and its adoption in all construction projects. Further research is however recommended on improving clients’ awareness and adoption of BIM. More so, simplified BIM training techniques and adoption framework are other areas for future research work.

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