Assessing the Key Barriers and Benefits of BIM Adoption in Nigeria

CHRISTOPHER CHIDI BELONWU
Department of Building, Niger Delta University, Wilberfoce Island, Bayelsa State, Nigeria

Abstract- Since the emergence of Building Information Modeling to the limelight of construction practice, several arguments have been advanced on its importance to the construction industry. It has been argued that it saves cost, and time, eliminates reworks, and encourages collaboration and communication among the construction team. On the other hand, several arguments have been advanced on the slow pace of its adoption. Some of the reasons advanced are the cost of infrastructure, software, training, and interoperability issues. Therefore, this study is aimed at assessing the barriers and benefits of BIM in Nigeria construction industry with a view to encouraging its wide acceptability. A mixed design was adopted where responses from respondents were received through questionnaires and interviews. The study shows that Software and training costs are barriers to BIM adoption while enhanced data management capabilities, collaboration, and communication are key benefits. Providing standard implementation guides and training can reduce the challenges.

Indexed Terms- Building Information Modeling, BIM adoption, barriers, construction industry, Nigeria, digital transformation

I. INTRODUCTION

Building Information Modeling is known for its integrated approach and collaborative nature, among Builders, Architects, Clients, Engineers, Manufacturers, Contractors, and other consultants. It is considered a process for enhancing construction management techniques (Onungwa et al., 2018). It involves a team-oriented strategy where the expertise of professionals involved in the design process is consolidated within a model. BIM technologies enable the representation, in three dimensions of designs and the incorporation of non-shape related information, into models.

The idea, behind the Building Information Modeling concept is to merge the details about the actual building structure into a model that encompasses architectural design data and other essential information required for constructing, operating, and maintaining the facility. The model encompasses a range of details including data, on the planned facility and structural specifics like design calculations outcomes and material information for construction purposes as well as installation plans and additional data related to project preparation and execution such as expenses and timelines in addition to land development considerations and other aspects of construction management, like safety and health (Araszkiewicz, 2015).

Various perspectives were taken into account when discussing BIM models. BIM usage began with defining the software technologies; however currently, it encompasses the functionalities that BIM provides under both "building information modeling" and "building information models". In this context, "modeling" involves the generation of the model using modeling software tools. The outcome of modeling efforts is a Building Information Model encompassed with data, on facility design and upkeep along with the behavior of these elements in scenarios as per the AGCO BIM Guide, from 2006. BIM models have applications such, as visualizing in 3 dimensions.

Furthermore, they are utilized for generating fabrication shop drawings, and conducting code reviews and forensic analyses. Furthermore, it is employed in facilities management and cost estimation. It also plays a role, in construction sequencing and detecting conflicts or collisions (Azhar et al., 2008).

Therefore, this study is aimed at assessing the key barriers and benefits of BIM adoption in Nigeria Construction Industry to encourage the relevant stakeholders on the need for a fast track of its implementation.

Obstacles to BIM Implementation

Building Information Modeling (BIM) is a digital portrayal of both the functional attributes of a structure or facility that plays a role, in decision-making across its entire lifespan. From conception to demolition as outlined in the NBIMS US (2016).

While Building Information Modeling offers advantages there are obstacles, to utilizing BIM software effectively in the Architecture, Engineering, and Construction (AEC) sector. There are challenges associated with the adoption of software in the construction industry such as high costs for software and training to keep up with rapid changes in technology trends. Additionally, older professionals and management may face difficulties in embracing software tools. There is also a shortage of personnel in the industry leading to a supply of qualified staff with specialized skills. Furthermore, implementations require changes and flexibility. Issues such, as supply chain alignment, IT literacy, staff resistance, legal uncertainties, interoperability problems, and unavailability of guidelines and benchmarks add to the complexities faced by professionals in adopting technologies.

In the study, by Ramilo and Embri (2014) they identified six factors that hinder innovation and BIM adoption, in companies; technological obstacles, financial constraints, organizational challenges, government regulations, psychological barriers, and procedural issues. Also, technical obstacles hinder the utilization of BIM in AEC education and the challenges of programming and software development like error identification and rectification by BIM software systems as well as constraints in component database options (Wong et al., 2011), the continual necessity for software and skills updates (Hancock, 2013), intricate user interfaces and availability of training resources as noted by Botchway et al., 2015. Technical obstacles can also arise when the development of models does not align with the construction sequence (Wong et al., 2011). There is also a challenge when mastering software and hardware/system specifications demands a significant amount of time (Al Saati et al., 2016).

Financial hurdles are an obstacle to adopting the Building Information Modeling practice as noted by Luomala (2020), the initial investment required for integrating technologies and processes may deter some businesses from embracing BIM at a stage leading to larger corporations with greater financial stability taking the forefront in transitioning to BIM practices.

Organizational and institutional obstacles are factors that exist within organizations and institutions such as the knowledge needed to operate BIM software and the shortage of teaching staff with expertise in construction to convert AEC needs into CAD/BIM instructional modules as noted by Wong et al., 2011. Many educational institutions face challenges such, as curricula (Becerik Gerber et al. 2011), developing curricula, and plans and integrating them effectively (McCuen 2014), and dealing with issues related to the quality of teaching staff and trained instructors. They also encounter problems like learning environments lacking settings for learning activities. Additionally, they may experience power supply outages, limited access to the internet well as concerns regarding security (Abubakir et al., Ibrahim & Kado and Bala, 2014; Kehinde, 2016), and access to the internet.

Governmental obstacles often revolve around concerns related to policies such, as the high costs of software in developing countries (Bui et al., 2016) along with ambiguous government regulations and the absence of clear standards in the AEC sector (Abubakar et al., 2013).

Personal obstacles can involve challenges that affect students and educators within their realm of influence such, as their teaching and learning approaches and personal characteristics as highlighted by Ozcan-Deniz, G. (2016), Petowska (2015), Botchway et al., (2015).

In Nigeria construction sector several obstacles hinder the use of BIM. A significant challenge is the shortage of workers with the right skills while most architects are self taught or learn while working. This deficiency of training often affects the understanding of emerging technologies and software capabilities. Moreover, many industry professionals are not up to date with the advancements. For BIM implementation, access to electricity and a reliable internet connection is essential. Access, to a reliable internet network is needed for downloading designs from a vendor websites; however, in Nigeria internet accessibility is limited which could potentially raise production costs when made available. According to Abubakir et al., (2014) the inconsistent power supply and lack of internet connectivity adversely impact productivity in office settings. Similarly, the continuous reliance on generators add to the expenses of running these offices. One more reason that hinders the acceptance of BIM is the resistance to change (Hassan and Yolles, 2009). Transitioning to BIM involves shifting the focus from creating drawings based on lines to crafting three designs that integrate elements, like walls, windows and doors.

Summarily, the obstacles that may affect BIM implementation such as the absence of supportive governmental policies and regulations to facilitate implementation efforts and the lack of concrete evidence showcasing the financial benefits involved in utilizing BIM technology. Furthermore, it is common for some individuals to mistakenly believe that BIM is only suitable for large scale projects while issues like corruption and lack of transparency can also pose challenges. Understanding the added value that BIM offers compared to 2 drafting systems can be a hurdle for some individuals as well as insufficient investments from both public and private sectors into BIM technology. Moreover, lack of measures to monitor and regulate the implementation of BIM technology pose as challenges along with the costs associated with its implementation, including expenses related to software, hardware and necessary training including a shortage of professionals for effective utilization of BIM tools coupled with a lack of demand from clients.

When it comes to using Building Information Modeling (BIM) software a major concern is the compatibility, among different software platforms available in the market today. Since the industry is still relatively new and evolving rapidly each software developer has its approach and features in their products. This diversity in software design poses a challenge for integration, between tools used by different team members involved in a project. As a result of these interoperability issues, it may become challenging for projects to progress smoothly if team members are using different software packages. The problem of interoperability extends beyond software platforms as newer versions of programs, within the platform can also face issues due, to the fast-paced growth of the BIM software industry.

Currently using 2 or 3-dimensional CAD drafting software means incurring expenses, for buying and maintaining software licenses to stay competitive in the market field. Recent data indicates that BIM software costs surpass those of CAD software in the market. The arrival of BIM software has also raised the demands on hardware significantly.

The expense of training is a factor when implementing software as there is a pressing need to efficiently educate staff to ensure the investment pays off in the long run. It is unrealistic to expect individuals to be proficient in CAD to easily, transition to using BIM software without specific training due to the distinct variances between the two systems. Training should be viewed as essential for all professionals engaged in designing and creating documentation given the substantial variances between BIM and CAD systems. Since BIM empowers all team members to participate in the design and modeling process and grants them authority over the product outcome, comprehensive training for pioneers allows them to gain an advantage on projects that necessitate defined specifications recorded through BIM technology.

Transition, from drafting to modeling involves a shift in workflow when transitioning from a CAD based drafting setup to a BIM based modeling environment. Tasks that used to be straightforward in drafting demand a skilled design drafter knowledgeable about the project and materials. Retaining a design modeler incurs higher costs compared to employing a draftsman without trade expertise. Certain companies might choose to avoid entering the realm of BIM because of the time and expertise required for it. Switching from CAD to BIM will require designers to take responsibility, for coordinating system components, with other design professionals like architects and engineers and minimizing site-related problems. Businesses have business models to ponder over when it comes to training their staff for BIM implementation.

The absence of guidelines is a notable issue concerning the extensive use of BIM-based design applications. This situation could potentially cause confusion among investors, designers, builders, and contractors regarding matters such as document delivery formats or the level of detail within the models. These conflicts may result in project delays at construction sites and ultimately lead to increased costs or prolonged legal disputes. Insufficient legal frameworks, for BIM, could hinder the adoption of the method due to issues, like cost and benefit distribution.

Benefits of BIM

The complete BIM model is essential for creating documentation that includes all functionalities and estimates in a coordinated manner; therefore, the model must be finalized before preparing any technical drawings to avoid delays in delivering documentation to the construction site early on in the project timeline. This approach necessitates a start to the design phase compared to methods and may require additional designers during the initial design stages.

Using building modeling provides advantages for users as it enhances communication, and efficiency, promotes collaboration among team members, streamlines operations, and ensures control over document sharing. The adoption of building information modeling (BIM) depends not on advancements but also on the involvement of individuals and the optimization of processes as highlighted in studies, by Wong & Fan (2013), Eastman et al., (2011), Arayici et al., (2011), and Khosrowshahi & Arayici (2012).

Building Information Modeling (BIM) enhances the design process compared to 2D drafting by enabling designers to visualize the building and its contents from different perspectives and identifying issues in advance to facilitate adjustments without costly alterations during the construction phase. BIM also enhances coordination among team members by providing data for each building component within its model. This allows access for all team members to information such as power usage and weight to ensure compatibility with other building components, under their purview. Using BIM enhances teamwork by ensuring that design modifications and their impacts are transparent to all users and model elements involved in the process. Team members can easily stay updated on each other's advancements without falling. Additionally, BIM allows for generation of room sections and elevations without starting from scratch or relying on the architect, for sketches. BIMs synchronized and collaborative approach enables the design team to detect clashes sooner among team members involved in the process. The early identification of conflict areas leads to prompt resolution of space allocation issues. This early clash detection helps in expediting the building design process and cutting down costs linked to rectifying clashes during design evaluations. Incorporating BIM makes interference detection straightforward. It involves pinpointing elements for scrutiny, generating a report. Clashes are also detected when elements are relocated or introduced.

BIM facilitates collaboration among CAD Designers, Architects, Builders, Engineers and clients, throughout the design phase making the process more efficient and effective. It involves the breaking down the project into phases to get inputs from different disciplines at each stage. This way, architects can explore innovative structural ideas without having to redo entire sections when engineers find design flaws. As the project nears completion, it will be quicker to obtain clash detection reports and verify all design elements efficiently. Enabling a process among team members with BIM technology in place is important for success. There is a distinction between BIM and traditional CAD in the collaborative features it provides to users. The essence of BIM lies in its focus on collaboration. However, when BIM is implemented than just as a marketing term it serves as a method to enhance the utilization of CAD through a fresh perspective, on data management. BIM and CAD are not entirely distinct; rather BIM represents an approach to fostering workflows within an environment facilitated by CAD tools.

The main contrast between BIM and 2 dimensional

CAD lies in the fact that the latter represents a structure through 2 perspectives like floor plans and elevations which stand alone from one another. When making changes to any of these views in 2 CAD software it's necessary to review and modify all views as well a tedious task prone, to errors that often leads to inadequate documentation. The information presented in these 2D sketches primarily consists of elements, like lines and shapes such as arcs and circles; whereas in BIM models with semantics intelligence, objects are described based upon building components such, as rooms and walls (CRC Construction Innovation, 2007). Simply put, the real essence of BIM lies in its ability to enhance communication and efficiency enough to warrant transitioning to software that prioritizes database storage first. Whenever a new software is employed to access design information everything is consolidated in one place, it makes access easy. Thus, enhancing teamwork capabilities, reduces the likelihood of errors or conflicts arising in designs, ensures the right utilization of materials. The project details and thorough scheduling information facilitate a reliance on prefabricated structural elements, from both quality control and logistical perspectives. This results in efficiency gains and cost reductions for the project while influencing decision making at every stage of the design process.

BIM also allows CAD designers to easily use drafting tools at a time without the need to update multiple files constantly. This can involve incorporating 3D models as the project progresses. In essence, BIM offers CAD designers the benefits it provides to the overall construction and design process which are flexibility, responsibility and oversight (Gray, 2020). Collision detection is another advantage of utilizing BIM. In design practices fields, coming together harmoniously is key; clashes are pinpointed by overlayed sketches to visually map out intersections clearly and adjust accordingly. When it comes to using CAD 2 systems, like colored layers that are compared visually directly on the computer screen. Also, 3D models have simplified the process of spotting collisions. In BIM technology, collision identification relies upon algorithms originating from the gaming industry and computer graphics development. BIM collision detection algorithms are designed for precision, over speed, in BIM systems by incorporating computer graphics techniques and adhering to industry standards and engineering practices to categorize detected collisions into three groups;

a. Striking impacts occur when two objects share a location.
b. Light collisions refer to the space required for installing components without obstruction or interference, in assemblies.
c. Analyzing the clash of technologies involves verifying the order of assembly and delivery timings as assessing the workforce availability and estimated construction duration required to finish the project.

Identifying collisions is seen as a benefit of using building information modeling as it helps to cut costs during the design phase and, on-site work. BIM has the capacity to enhance communication and collaboration, among project participants offering advantages that extend from enhancements, in effectiveness and coordination to heightened client contentment.

Moreover, BIM provides integrators with enhanced precision when estimating quantities. The inclusion of metadata to objects facilitates quantity calculations and cost estimation thereby enhancing the accuracy of project bids and pricing. Designers experience a decrease in requests for information and change orders. Integrators can visually map out schedules based on material availability and construction progress. This feature enables project managers to efficiently adjust construction timelines in response to fluctuating material delivery expenses and availability. By minimizing errors and omissions BIM aims to lower instances of claims and professional liabilities. Decreasing insurance expenses and bonding fees, while enhancing the reputation of a company are expected to expand the range and size of projects to design and integration firms.

Moreover, professionals involved in the procurement of construction projects can digitally transfer modeled building information from the design team comprising the architect and various engineers, to the contractors as well as subcontractors and suppliers working on the project. This process aids in minimizing information loss and streamlining communication compared to design and drafting methods. A level of proficiency in BIM technology facilitates improved clash detection as highlighted by Chen and Baddeley (2015).

II. RESEARCH METHODOLOGY

This study utilized a research approach that incorporated both qualitative methods for a comprehensive analysis of the topic at hand. The flexibility of this method allows for the integration of research techniques associated with both quantitative and qualitative approaches resulting in the advantage of triangulation. One advantage of this method is their ability to provide an insight into contextual issues which has been particularly useful, in identifying the challenges and advantages of implementing BIM in the research location as well as determining the benefits of BIM usage. Conversely, one key benefit of using methods is their capacity to generalize results by gathering data and employing statistical analysis techniques.

This study was conducted in the Federal Capital Territory, Abuja, Nigeria while the respondents were registered construction professionals practicing in Abuja. Based on the data obtained from the professional bodies the study population was ascertained to be 3992 and using Yamane's (1967) formula, the sample size was determined to be 364.

Secondary data were collected from published and unpublished journal articles, conference and workshop proceedings, textbooks, and web sources. Primary data were collected using structured questionnaires that were ranked from Very Likely (5) to Very Unlikely (1) and an oral interview recorder with Voice Recorder v2.3.0-202103241913. Respondents were carefully selected to ensure that participants had an interface with BIM prior to the interview session or filling out the questionnaire.

Data obtained were analyzed using Frequency and Percentage Distribution, Weighted Mean and Standard Deviation, One Sample t-test, and Principal Component Analysis (PCA).

III. RESULTS AND DISCUSSION

Table 1.0 Responses on Barriers and Benefits of BIM Adoption

Factors	VL (5)	L(4)	N(3)	UL(2)	VU(1)	Mean ± SD	WiXi
The advocacy for BIM adoption has been intense and sufficient.	0	52	90	103	39	2.55 ± 0.94	723
The cost of software is one of the challenges of BIM adoption.	116	103	52	13	0	4.13 ± 0.87	1174
Improved visualization, and collaboration, are some of the benefits of BIM.	90	136	58	0	0	4.11 ± 0.71	1168
Providing standards can reduce the challenges of BIM adoption.	123	123	26	6	6	4.24 ± 0.86	1203
Stakeholders have roles to play in overcoming BIM adoption challenges.	149	104	19	6	6	4.35 ± 0.86	1236
BIM adoption will enhance the understanding of building models.	155	116	13	0	0	4.50 ± 0.59	1278

Very Likely (VL) = 5, Likely (L) = 4, Neutral (N) = 3, Unlikely (UL) = 2, Very Unlikley (VU) = 1

The results in Table 1.1 is generated based on the research aim. It uncovered the barriers and benefits of Building Information Modeling (BIM) adoption among workers in Abuja. As presented in the result, the major impediment to BIM adoption is the cost of software, compatibility between software platforms, cost of training and transition from drafting to modeling (mean=4.13>3.00). Also, another challenge to BIM adoption is that advocacy for BIM adoption has not been intense and sufficient. These views align with the reviewed works of Wong et al. (2011), Botchway et al. (2015), and Luomala (2020). On the other hand, since BIM adoption will enhance data management capabilities, collaboration, communication, and client understanding of building models (mean=4.50>3.00), providing a standard implementation guide, training, and conducting training using professionals can reduce the challenges of BIM adoption in the area (mean = 4.24). In addition, since the adoption of BIM will bring about improved visualisation, collaboration, coordination, reduction in the cost of software, conflict resolution, and increased quality in the construction sub-sector (mean = 4.11), Government, Industry and Professionals have significant roles to play to defeat BIM adoption challenges (Mean = 4.35), especially among professionals in Abuja. To single out the major barrier to BIM adoption in the construction industry, the study utilized the exploratory principal component method of factor analysis. Scree plot of the factor analysis is provided in Figure 1.0:

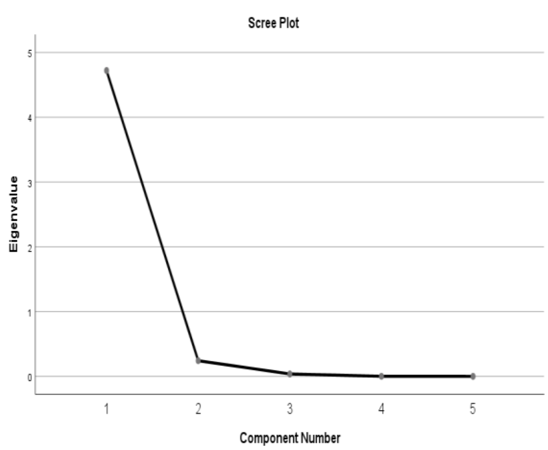

Fig. 1.0: Scree Plot of the Barriers and Benefits of BIM Adoption.

The scree plot shows a level-off from component number 2, thereby indicating that only one factor can be explained to be substantial for the adoption of BIM in the area. The correlation matrix showing the result of the interrelatedness of the component factors is shown in Table 1.2

Table 1.2 Correlation Matrix of Test of Interdependence

		X1	X2	X3	X4	X5
Correlation	X1	1.000				
	X2	.927	1.000			
	X3	.965	.919	1.000		
	X4	.945	.809	.969	1.000	
	X5	.949	.832	.980	.998	1.000

This matrix is not positive definite.

Where,

X1 = Cost of software, compatibility between software platforms, cost of training, and transition from drafting to modeling are some of the challenges of BIM adoption.

X2 = Improved visualisation, collaboration, coordination, Cost of software, conflict resolution, and increased quality are some of the benefits of BIM adoption.

X3 = Providing a standard implementation guide, training, and conducting training using professionals can reduce the challenges of BIM adoption.

X4 = The Government, Industry, and Professionals have significant roles to play in overcoming BIM adoption challenges.

X5 = BIM adoption will enhance data management capabilities, collaboration, communication, and client understanding of building models.

The correlation result shows a high degree of interrelatedness among the factors (r≥0.70). The implication is that the factors are highly dependent on themselves; hence, the need to sieve out the most important ones.

Table 1.3 Component Scores Coefficient Matrix (Varimax with Kaiser Normalization method)

Factors	Component	Communalities
Cost of software, compatibility between software platforms, cost of training, and transition from drafting to modeling are some of the challenges of BIM adoption.	.209	.971
Improved visualization, collaboration, coordination, Cost of software, conflict resolution, and increased quality are some of the benefits of BIM adoption.	.195	.850
Providing a standard implementation guide, training, conducting training using professionals can reduce the challenges of BIM adoption.	**.211**	.990
The Government, Industry and Professionals have significant roles to play in overcoming BIM adoption challenges.	.206	.947
BIM adoption will enhance data management capabilities, collaboration, communication and client understanding of building models.	.208	.962
Eigenvalue = 4.721		
%age of Variance Explained = 94.415		

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

From the principal component analysis result, it was ascertained that the major Barrier of BIM Adoption in the construction industry is providing standard implementation guides, training, and conducting training using professionals. This factor has an eigenvalue of 4.721 and explains about 94.42% of the total variations in the system.

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