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Adoption of building information modelling for post-construction in Nigeria: examination of barriers and strategies development

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Abstract

Purpose – Despite successfully adopting building information modelling (BIM) for design and construction, its adoption in post-construction is critically lagging. This study aims to investigate the adoption of BIM for post-construction in Nigeria. Specifically, it aims to investigate the barriers hindering BIM adoption, propose strategies to facilitate its integration into the post-construction phase and examine the relationship between the barriers and strategies towards adopting BIM for post-construction.

Design/methodology/approach – This study employs a quantitative approach to gather numerical data on BIM perceived barriers among International Facility Management Association (IFMA) members. The study also develops strategies from an extensive literature review and combines them with insights from preliminary investigation. The data were analysed using descriptive and inferential statistics.

Findings – The top perceived barriers among the professionals are lack of BIM awareness, software availability issues and difficulties using new technologies. Institute training/workshops on BIM software for the professionals in the organisation, including BIM software courses in various related professional exams, and encouraging adoption of BIM from the grassroots, such as higher institutions, emerge as the top strategies. The findings further show a significant relationship between the barriers and strategies, emphasising the recognition that understanding barriers prompts the active development and implementation of strategies.

Originality/value – This study holds originality in its examination of the relationship between the barriers and strategies associated with BIM adoption in Nigerian Architecture, Construction, Engineering and Operation.

Keywords Barriers, Building information modelling, Developing countries, Post-construction, Strategies, Technology application

Paper type Research paper

Introduction

The Architecture, Construction, Engineering and Operation (AECO) industry is a pivotal sector of every nation and the global economy, contributing significantly to the global gross domestic product (GDP) (Bello *et al.*, 2023a). However, despite holding a significant position, it faces numerous bottlenecks. These challenges include poor productivity and ineffective communication, amongst many others. According to Bello *et al.* (2022), Parn and Edwards (2019), this is due to the industry's unwillingness to incorporate innovative technologies such as BIM, blockchain, IoTs and other innovations. However, adopting innovative technologies like BIM is crucial to enhance information management and optimise building life cycle performance (Olanrewaju *et al.*, 2021).

BIM has been widely applied and intensively researched during the planning, design and construction stages. However, its application in the post-construction phase is still significantly limited (Bello and Ayegba, 2023). Planning, design, construction and post-construction should all be considered when determining a project's success (Olanrewaju *et al.*, 2021). Realising projected benefits and maintaining standards while managing buildings effectively and efficiently during post-construction operations has become a significant problem. Despite the numerous benefits of BIM throughout the project life cycle, its

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acceptance in the post-construction stage remains limited (Durdyev *et al.*, 2021). South Africa is the only African country developing significantly in BIM utilisation (Chioma *et al.*, 2020).

Post-construction refers to the activities and processes after completing a construction project (Bello and Ayegba, 2023). It involves maintenance, inspection, quality assurance and necessary repairs or improvements to ensure the constructed facility continues functioning effectively and safely over its intended lifespan. Professionals typically manage facilities manually, where data entry is time-consuming and prone to human errors and omissions (Matarneh *et al.*, 2022). The conventional operational approach often leads to inadequate documentation, delays transitioning from construction to post-construction phases and extended working hours (Ikediashi *et al.*, 2022; Olanrewaju *et al.*, 2022). Utilising BIM during the post-construction phase of a building enhances the performance of both facilities and assets (Chioma *et al.*, 2020).

The application of BIM in post-construction activities offers several potential benefits, including digital data storage, energy monitoring and control, clash detection, space management and proactive maintenance, as highlighted (Durdyev *et al.*, 2021). BIM facilitates cost management across the entire life-cycle of a building and empowers facility managers to participate in decision-making during the planning, design and construction phases when their input can be most influential. BIM provides comprehensive facility knowledge that can assist facility experts throughout the operational lifespan of the facility (Valinejadshoubi *et al.*, 2022). However, it is worth noting that the adoption of BIM in the post-construction stage remains relatively low, notably in developing countries (Olanrewaju *et al.*, 2021; Chioma *et al.*, 2020). This suggests the need for greater awareness and broader adoption among stakeholders in the post-construction phase, which is still in its early stages.

Several studies have established the post-construction phase as the most extended and essential project life-cycle (Hilal *et al.*, 2019; Hosseini *et al.*, 2018). More than 85% of the total cost of ownership of the facility is related to its administration and operation (Lewis *et al.*, 2010). According to Durdyev *et al.* (2021), future studies should investigate the barriers to adopting BIM in other sectors during the post-construction phase, focus on developing nations and conduct comparison studies between nations. According to Chioma *et al.* (2020), African countries are the only continent significantly lagging in the race and benefits of BIM adoption.

Hence, this study has a threefold purpose: Firstly, it investigates barriers to BIM adoption in post-construction in Nigeria, focussing on International Facility Management Association (IFMA) registered professionals in Abuja. Leveraging their expertise in facility management, these professionals provide insights into integrating BIM into post-construction. Secondly, the study develops fifteen potential strategies from existing literature and preliminary investigations to address identified barriers. IFMA members rank these strategies to measure their perceived effectiveness in overcoming obstacles in practical BIM implementation. Lastly, the study comprehensively examines the relationship between identified barriers and strategies to understand BIM adoption dynamics in Nigerian post-construction. Through this approach, the study contributes insights to enhance BIM adoption in the Nigerian AECO industry.

Literature review

Overview of related study

The exploration of BIM adoption and implementation through the lens of literature offers a comprehensive view of the current research landscape. Okwe *et al.* (2022) examine the barriers to BIM-FM integration in Lagos, such as insufficient awareness levels of BIM–FM integration benefits, non-existence of contractual and legal framework for BIM implementation, limited studies on BIM–FM inter-relationship, poor acceptance levels and resistance to change among stakeholders, emphasising the necessity of addressing these obstacles for successful implementation. Similarly, Olapade and Ekemode (2018) uncover a low level of awareness and adoption of BIM in FM among professionals in Lagos, providing insights into potential integration strategies. Focussing on residential real estate development in Ekemode and Olapade (2021) underscores the imperative for increased awareness and usage of transformative BIM technology.

Ikediashi *et al.* (2022) pinpoint a lack of awareness, poor infrastructure and poor education/training as critical barriers to BIM-FM adoption, stressing the need for targeted measures. Anih *et al.* (2019) stress the importance of awareness and training to assess the practicability and barriers of BIM for managing public buildings. Ajayi (2022) exploration of BIM adoption in the Nigerian FM industry reveals poor awareness among professionals, suggesting training, incentives and policies to support implementation. Evaluating essential requirements for BIM implementation in maintenance management in South Africa, Akinradewo *et al.* (2023) identify training, increased awareness and owner support as crucial. Adetayo and Onatayo (2023) scientometric review emphasises the need for increased awareness and government effort in BIM-FM research.

Relatedly, Abuja, Adelusi *et al.* (2021) evaluate factors influencing BIM adoption in FM, emphasising top management commitment and practical measures for adoption. Oluleye *et al.* (2023) integrate BIM to improve FM operations, using a fuzzy synthetic approach to evaluate critical success factors and provide a roadmap for facility managers and policymakers.

Despite the existing body of research on BIM adoption in the field, the barriers to its effective implementation persist in Nigeria. This persistence can be attributed to the limitations of previous studies, which have not fully addressed the specific and broader professional context and have inadequately developed strategic approaches to overcome these barriers. This study aims to bridge these knowledge gaps. The literature on BIM adoption in the post-construction phase lacks a focused exploration of the BIM challenges regarding IFMA professionals in Abuja. Abuja is Nigeria's capital, making it a fast-growing city with modernised and smart buildings. Additionally, there is a gap in understanding the nuanced correlation between BIM barriers and strategies. Furthermore, there is a need for a comprehensive study that integrates more comprehensive analytical approaches as compared to the literature. The research aims to address these gaps by offering targeted insights by examining only IFMA professionals in Abuja, exploring the intricate relationship between barriers and strategies, and employing a multifaceted analytical approach.

Barriers to BIM towards post-construction

Globally, strategies through various approaches are introduced to mitigate the barriers hindering the adoption of BIM. It is envisaged that improved design optimisation through inquiry and appraisal of design alternatives will produce more efficient buildings (Tuohy and Murphy, 2016). According to Arayici *et al.* (2012), inefficient facility operation costs the United States of America approximately $11 billion annually. This situation demands quick attention. According to Hu *et al.* (2018) estimates, operating issues caused by inaccurate information and interoperability cost the US $10.6 billion yearly.

According to the literature, BIM adoption is very low for post-construction activities. Some of the reported barriers to BIM application include higher training costs (Bello and Ayegba, 2023), higher tool costs (Ahmed, 2018), inadequate guidelines (Naghshbandi, 2016), a lack of regulatory policies (Li *et al.*, 2019), an absence of BIM training and resistance to change (Durdyev *et al.*, 2021). Several governments have committed to adopting BIM, but the lack of rules has prevented them from achieving it effectively (Valappil and Saleeb, 2016).

According to studies (Walasek and Barszcz, 2017; Ademci and Gundes, 2018; Sun *et al.*, 2017; Tan *et al.*, 2019), the difficulties faced were continual and constant. BIM adoption in emerging nations like Nigeria is slower than anticipated compared to developed economic nations where it is strong (Ullah *et al.*, 2019; Akerele and Etiene, 2016). Lack of government support, a lack of retraining for experienced members on BIM use and application, a lack of initiative and education, the inability to change current work practises and a lack of clarity regarding the roles and advantages of using a BIM approach are an among factors that prevent the adoption of BIM in developing economies (Ismail *et al.*, 2017). Table S1 compiles and presents these barriers.

Strategies for implementation of BIM for post-construction

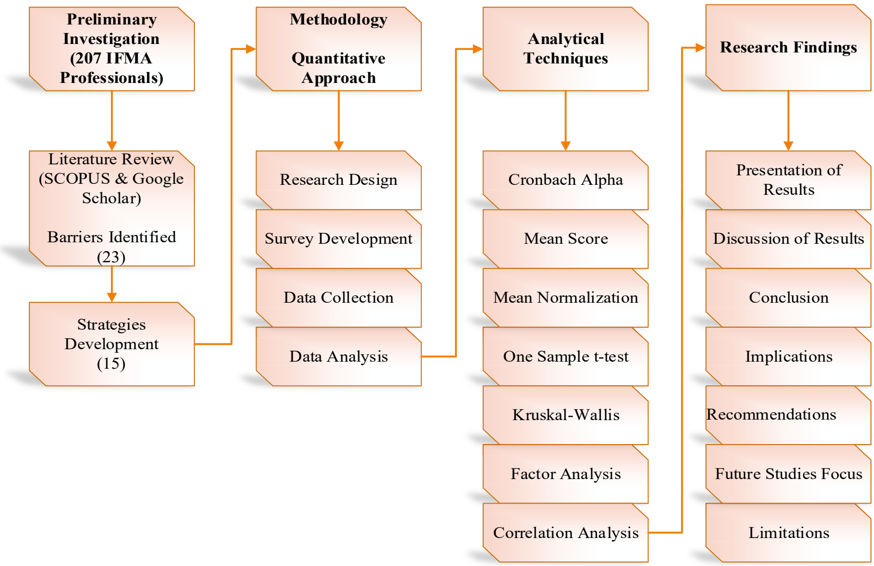
Countries like the United States, the United Kingdom, Germany, Canada and France are leading the way in adopting BIM. These countries were swiftly followed by others like Australia, Brazil and Japan (McGraw-Hill Construction, 2014). According to Kassem and Succar (2017), the USA has long been a global leader in this process. According to the UK government's implementation plan, which is regarded as the most successful strategy in the world, BIM was required for usage in all government projects by 2016. Scandinavian countries, including Finland, Norway and Denmark, are world leaders in BIM adoption. To establish a standard in the European Union, they established industry-wide standards, and the development of these regulations sparked interest on a global scale (Smith, 2014).

Ma *et al.* (2020) highlight five key BIM strategy approaches: governance development, accommodation modifications, technology space, resources and collaboration. By creating a BIM institution for graduate training, discouraging clients from using redundant building techniques by raising the cost and creating enforcement organisations for BIM implementation, Aka *et al.* (2021) developed the fundamental strategies for overcoming the barriers to BIM adoption. An up-down strategy that encourages the effective sharing of data is required for the adoption of BIM to be successful in Saudi Arabia, according to research on the strategies and problems for deploying BIM tools in the country (Alhumayn *et al.*, 2017). Considering it from the contractor's standpoint during the tendering process, implementing a BIM strategy affects the probability of winning the contract (Majzoub and Eweda, 2021). Stakeholders, including government agencies, academic institutions and researchers, may be involved in decreasing the difficulties of embracing BIM for use in the administration of general facilities, but the obstacles are pertinent.

Methodology

Research design: This study uses a quantitative research approach, usually connected with employing a questionnaire to gather quantitative data that is statistically evaluated (Saunders *et al.*, 2016). Figure 1 shows the study framework. The first step in creating a sample design for a study is to explicitly describe the group of items to be considered, often known as the population to be examined (Kothari, 2004). The study sampling frame in this investigation consists of IFMA-registered professionals in Abuja. The census approach was employed for its appropriateness when the population size is relatively small and well-defined (Saunders *et al.*, 2016). Abuja is considered for this study for two reasons: firstly, Abuja is the capital of Nigeria, which makes it a fast-growing hub for modernised and smart buildings; secondly, limited studies have examined professionals in this region.

Survey development: A well-structured questionnaire using a five-point Likert scale was developed based on the literature review using SCOPUS and Google Scholar to ensure comprehensive capturing of barriers and strategies. The search keywords include "Building Information modelling", "barriers or challenges", "strategies" and "post-construction or facility management". These specific keywords ensure results in tailored and comprehensive articles. Before data collection, some strategies were developed during the preliminary investigations and through the author's field knowledge. The Likert scales are excellent for defining respondents'



Source(s): Authors creation

Figure 1.
Study framework

opinions on various statements (Collins, 2010). The initially developed questionnaire was subjected to a pilot test to ensure the collection instrument was free from ambiguity and that intended respondents would easily understand the questions. The questionnaire was distributed to ten experts, including five industry professionals and academicians; all ten questionnaires were retrieved and considered in developing the final questionnaire.

Data collection: According to the preliminary investigations, there were 207 IFMA-registered professionals in Abuja at the time of data collection. Consequently, purposeful sampling, a non-probability sampling technique involving choosing participants based on a predetermined goal or criterion, was adopted. Purposive sampling efficiently ensures that the research focuses on the appropriate population (Saunders *et al.*, 2016). However, establishing the criterion for participant selection was the first step in the purposive sampling process. The study set the listed criteria to select IFMA professionals in Abuja:

(1) The participants must be registered members of IFMA in Abuja.

(2) Participants must have a minimum of one year of experience in facility management.

Purposive sampling ensures that the research is focused on a particular group, which increases the likelihood of gathering correct and pertinent data (Saunders *et al.*, 2016).

Only 164 of the 207 IFMA professionals could obtain the questionnaire due to a lack of access to all the respondents. Of the 164 physically shared questionnaires, 148 were retrieved during data collection and 132 (63.77%) were deemed adequate based on previous related studies (Ikediashi *et al.*, 2022; Okafor *et al.*, 2022). Any questionnaire with unanswered questions or multiple answers to the same question was excluded from the study.

Data analysis approach

The collected survey data underwent a comprehensive analysis employing diverse analytical techniques, including mean ranking (MS), one-sample *t*-test, one-way ANOVA (Kruskal–Wallis), and factor and correlation analysis. These analyses were conducted using SPSS V26.

The reliability of the study data was assessed through a reliability test (Cronbach alpha), yielding a commendable value of 0.862. This value surpasses the recommended minimum threshold of 0.70, as outlined by Maree and Pietersen (2016).

Presentation of results

Overview of respondent's background. The respondents' characteristics were assessed based on their academic qualifications, professions, age groups, genders, registrations with IFMA, years of experience, client types and firm sizes. The survey revealed that 6.82% of respondents hold an HND, 4.55% possessed a Post Graduate Diploma, 46.97% had a Bachelor's degree, 36.36% held a master's degree and 5.30% earned a doctorate. The respondents included 6.06% architects, 25% Builders, 12.88% engineers, 44.70% Estate surveyors, 0.76% Project Managers and 10.61% Quantity surveyors. The distribution of respondents' age shows: 0.76% were in the 18–24 years bracket, 25–34 years (31.82%), 35–44 years (43.18%), 45–55 years (21.97%) and 55 years or older (2.27%).

As a registered member of IFMA, 4.55% had been registered for less than five years, 43.18% had been members for 5–10 years, 37.12% for 10–15 years, 9.85% for 15–20 years and 5.30% for 20 years or more. Regarding their work experience, 3.03% had less than five years of experience, 37.12% had 5–10 years of experience, 42.42% had 10–15 years of experience, 9.85% had 15–20 years of experience and 7.85% had over 20 years of experience. The results also indicate that 29.55% of the respondents were employed in government establishments, while 70.45% worked in private organisations. Additionally, 4.55% of respondents were employed in large firms (250 employees or more), 44.70% in medium-sized firms (50–249 employees) and 50.76% in small firms.

Barriers and strategies towards adoption of BIM for post-construction. Table 1 shows the crucial barriers (23) and strategies (15) towards adopting BIM in the Nigerian AECO industry post-construction. The mean score ranges from 0.451 to 3.92 for the barriers and 4.89 to 4.09 for the strategies. Further, all barriers and strategies were determined to be significant ($p < 0.05$) using a one-sample *t*-test threshold of 3.5. Since all the factors are above the set threshold, a normalisation (Norm.) technique was adopted to determine the most critical factors ranked by the professionals by adopting a threshold of 0.5 above as critical factors. Normalisation involves adjusting numerical values to a standard scale, usually between 0 and 1. This approach was adopted in previous related studies (Al-Mohammad *et al.*, 2023).

The most crucial barrier, underscored by the normalisation value of 1.00, is the "Lack of BIM Awareness," emphasising the need for comprehensive awareness campaigns and educational initiatives to bridge knowledge gaps within the industry. Followed by "Software Availability Issues," (Norm. = 0.92) signalling the importance of addressing gaps in software availability to streamline the BIM adoption process, "Difficulties in using new technologies" (Norm. = 0.80), highlighting the necessity of overcoming challenges related to technological adaptation and enhancing digital literacy within the industry.

On the strategies, "Institute Training/Workshop on BIM Software" achieved the highest normalisation value of 1.00, underscoring the critical role of structured educational programs in enhancing professional competence. "Include BIM software courses in professional exams" (Norm. = 0.98), emphasising the integration of BIM education into the broader professional examination curriculum. Additionally, "Encourage grassroots adoption of BIM" (Norm. = 0.95) highlights the importance of fostering flexibility among industry stakeholders and institutions to encourage widespread adoption. "Encourage flexibility among industry stakeholders" (Norm. = 0.89), emphasising the importance of promoting flexibility and adaptability within the industry to facilitate BIM adoption. The strategy advocating for "Higher priority for BIM projects in urban approval" (Norm. = 0.86) sheds light on economic considerations that can drive successful BIM implementation. These

Table 1. Barriers and strategies

Code	Barriers	MS	Norm	SD	Test value = 3.5 t	df	Sig	K-W	R	Code	Strategies	MS	Norm	SD	Test value = 3.5 t	df	Sig	K-W	R
BR1	Lack of BIM awareness	4.51	1.00	0.85	13.59	131	0.000*	0.503	1	SR15	Institute training/ workshop on BIM software for the professionals in the organisation	4.89	1.00	0.43	37.02	131	0.000*	0.728	1
BR22	Software availability issues	4.46	0.92	0.83	13.18	131	0.000*	0.012	2	SR14	Include BIM software courses in various related professional exam	4.87	0.98	0.45	34.82	131	0.000*	0.944	2
BR9	Difficulties in using new technologies	4.39	0.80	0.84	12.07	131	0.000*	0.073	3	SR8	Encourage adoption BIM from the grassroots (e.g. Higher institutions)	4.85	0.95	0.55	28.41	131	0.000*	0.874	3
BR15	Perception towards BIM in generality	4.32	0.68	0.84	11.18	131	0.000*	0.646	4	SR13	Establish a Bi-annual training/workshop by the professional bodies (e.g. IFMA)	4.82	0.91	0.49	30.82	131	0.000*	0.343	4
BR13	Lack of technological readiness	4.28	0.61	0.80	11.15	131	0.000*	0.663	5	SR12	Encourage flexibility among industry stakeholders towards accepting new technologies	4.8	0.89	0.52	28.60	131	0.000*	0.379	5
BR19	Return on Investment (ROI) issues	4.25	0.56	0.85	10.13	131	0.000*	0.442	6	SR10	Higher priority should be given to projects prepared by BIM software than one prepared with traditional method during urban approval	4.78	0.86	0.53	27.82	131	0.000*	0.807	6
BR2	Lack of expertise within the organisations/Field	4.21	0.49	0.89	9.11	131	0.000*	0.712	7	SR9	Encourage interoperability among the professionals	4.77	0.85	0.55	26.74	131	0.000*	0.534	7

(*continued*)

Table 1.

Code	Barriers	MS	Norm	SD	Test value = 3.5 t	df	Sig	K-W	R	Code	Strategies	MS	Norm	SD	Test value = 3.5 t	df	Sig	K-W	R
BR12	Poor acceptance levels and resistance to change among stakeholders	4.20	0.47	0.9	8.87	131	0.000*	0.663	8	SR11	Projects carried out with BIM should be cheaper than project done with traditional method	4.76	0.84	0.54	26.74	131	0.000*	0.265	8
BR5	Ambiguity in model information update	4.18	0.44	0.91	8.64	131	0.000*	0.692	9	SR3	Create easy access to BIM software	4.27	0.23	0.68	13.10	131	0.000*	0.257	9
BR8	Non-existence of contractual and legal framework for BIM implementation	4.17	0.42	0.86	9.00	131	0.000*	0.002	10	SR7	Enforcement of the government policy	4.23	0.18	0.68	12.23	131	0.000*	0.904	10
BR17	Lack of relevant legislation	4.17	0.42	0.84	9.19	131	0.000*	0.032	11	SR4	Sensitise and encourage clients to use BIM software for their projects	4.19	0.13	0.74	10.66	131	0.000*	0.442	11
BR14	Insufficient awareness levels for BIM and post-construction integration benefits	4.17	0.42	0.75	10.17	131	0.000*	0.216	12	SR1	Increase the level of awareness among the professionals and stakeholders	4.17	0.10	0.86	9.00	131	0.000*	0.043	12
BR10	Unavailability of BIM requirements	4.11	0.32	0.84	8.35	131	0.000*	0.365	13	SR2	Affordable procurement of the BIM software	4.14	0.06	0.69	10.73	131	0.000*	0.298	13
BR20	Lack of infrastructure	4.10	0.31	0.69	10.02	131	0.000*	0.360	14	SR6	Government policy	4.11	0.03	0.84	8.45	131	0.000*	0.827	14
BR4	Lack of client demand	4.09	0.29	0.86	7.89	131	0.000*	0.633	15	SR5	Create enabling environment within the industry	4.09	0.00	0.75	9.10	131	0.000*	0.013	15
BR16	Inadequate regulatory procedures	4.07	0.25	0.89	7.31	131	0.000*	0.390	16										
BR7	Interoperability issues	4.06	0.24	0.81	7.97	131	0.000*	0.355	17										

(*continued*)

Code	Barriers	MS	Norm	SD	Test value = 3.5 t	df	Sig	K-W	R	Code	Strategies	MS	Norm	SD	Test value = 3.5 t	df	Sig	K-W	R
BR11	Limited studies on BIM and post-construction inter-relationship	4.05	0.22	0.93	6.73	131	0.000*	0.116	18										
BR23	Lack of training and skills	4.01	0.15	0.96	6.07	131	0.000*	0.610	19										
BR3	Lack of collaboration among stakeholders	3.98	0.10	1.07	5.11	131	0.000*	0.971	20										
BR21	Absence of benchmark for quality	3.97	0.08	0.78	6.91	131	0.000*	0.609	21										
BR6	Inadequacy of mode data	3.92	0.00	0.85	5.65	131	0.000*	0.084	22										
BR18	High Investment Cost	3.92	0.00	0.89	5.37	131	0.000*	0.376	23										

Source(s): Authors analysis

Table 1.

normalisation values offer nuanced insights into the relative significance of each barrier and strategy in Nigeria's unique context of post-construction.

Kruskal–Wallis (K-W) test was conducted based on the respondents"' professions (Architect, Builder, Engineer, Estate Surveyor, Project Manager, Quantity Surveyor) to explore the respondents" varied viewpoints on the barriers impacting the adoption of BIM for post-construction in Nigeria. Table 1 reveals no statistically significant ($p < 0.05$) differences in opinion in the ranks of the identified barriers and strategies among the professionals. The study shows that, despite their varied professional backgrounds, they agreed on the significance of the identified factors, similar to construction-related study outcomes (Bello *et al.*, 2023b).

Factor analysis (preliminary test). Factor analysis was performed to examine and categorise the variables into smaller components. The barriers and strategies were subjected to the KMO measure of sample adequacy (MSA) and BTS to determine whether the data were suitable for further analysis. Thus, the two criteria establish the threshold at which data must be obtained before further analysis is deemed appropriate. The KMO ranges from 0 to 1, with 0.50 as a good starting point (Field, 2013). The identity matrix and the correlation matrix are compared using the BTS to determine whether there is a significant difference. To be deemed adequate for analysis, the data must reach the BTS significance criterion (Field, 2013). The KMO values of 0.779 and 0.769 were achieved for barriers and strategies, respectively, and the BTS value was significant at $p = 0.000$. The KMO values of 0.779 and 769 are higher than the suggested value of 0.6 by Kaiser (1970), and the BTS by Bartlett (1954) was statistically significant; therefore, the data are adequate for factoring.

Factor analysis test for barriers and strategies. The barriers and strategies are established to be suitable for factor analysis. Hence, principal component analysis (PCA) and eigenvalue were selected as the choice criteria (Pallant, 2007). A loading factor of 0.5 benchmark was adopted. The sum of the four rotations and total cumulative percentages equals 57.316% for barriers, and the strategies (3 rotations) with a cumulative percentage of 61.560% are shown in Table S2. This is consistent with the least 50% criterion for variables (Pallant, 2007). The barriers and strategies were subsequently presented and discussed based on their components.

Presentation of barriers clusters

Technological integration barriers. This category highlights the barriers to integrating BIM technologies into post-construction operations. Experts may find it difficult to adjust to new technology (BR9); hence, research into efficient training programmes and intuitive user interfaces is necessary. To improve professionals' comprehension of the advantages of BIM, extensive educational programmes and communication tactics are needed to address the lack of awareness (BR1). The lack of technological readiness (BR13) highlights the necessity of conducting studies to evaluate the technological infrastructures of organisations and provide methods to enhance their preparedness. Return on Investment (ROI) concerns (BR19) highlight the financial aspects of adopting BIM. Software availability difficulties (BR22) highlight how crucial it is to assess the state of BIM software today, pinpoint its shortcomings and offer suggestions to industry and software development stakeholders.

Data and information infrastructure barriers. In the context of adopting BIM, this category focuses on issues with data, information and infrastructure. The insufficiency of model data (BR6) emphasises how crucial it is to guarantee the quality and accessibility of data for BIM procedures. The lack of customer demand (BR4) and a quality benchmark (BR21) indicate the necessity of industry-wide norms and procedures. Interoperability problems (BR7) emphasise how important it is for various BIM platforms and tools to work together seamlessly. Model information update ambiguity (BR5) emphasises the importance of precise, standardised procedures for upgrading BIM models. Insufficient infrastructure (BR20) suggests that the BIM deployment infrastructure must be assessed and improved.

Regulatory compliance and expertise barriers. This component focuses on the barriers to BIM adoption related to knowledge, procedures and regulations. Insufficient regulatory protocols (BR16) underscore the necessity of all-encompassing regulatory structures that facilitate the integration of BIM. The significance of acquiring expertise through training programmes and educational activities is emphasised by the absence of knowledge within organisations/fields (BR2) and the lack of training and skills (BR23). Excessive investment costs (BR18) indicate that cost-effective BIM adoption strategies should be investigated. Research on efficient legislative frameworks, educational initiatives and cost-benefit evaluations to encourage proficiency and compliance are necessary to address these issues.

Stakeholder collaboration and awareness barriers. This component includes issues with stakeholder participation, awareness and collaboration. The absence of cooperation among stakeholders (BR3) suggests that the industry needs to cultivate a collaborative culture. Insufficient pertinent legislation (BR17) underlines how crucial it is to match legal frameworks with the deployment of BIM. Few studies on building information modelling (BIM) and post-construction interrelationships (BR11) point to a knowledge vacuum in academia that could influence business procedures. The benefits of post-construction integration (BR14) and BIM are poorly understood, emphasising the significance of focused awareness initiatives. The lack of BIM requirements (BR10) suggests that industry-wide standards and guidelines are required.

Presentation of strategies clusters

Promoting BIM awareness and skill development. This category involves strategies to enhance awareness, skills and acceptance of BIM within the industry. Instituting training/workshops on BIM software for professionals (SR15) underscores the importance of continuous learning and skill development. Encouraging flexibility among industry stakeholders towards accepting new technologies (SR12) emphasises the need for an adaptable industry culture. Giving higher priority to projects prepared by BIM software during urban approval (SR10) suggests leveraging regulatory processes to incentivise BIM adoption. Including BIM software courses in various related professional exams (SR14) aims to integrate BIM education into professional development. Encouraging interoperability among professionals (SR9) underscores the importance of seamless collaboration in BIM processes. Encouraging the adoption of BIM from the grassroots (SR8) focuses on building a foundation for future professionals. The idea that projects carried out with BIM should be cheaper than projects done with the traditional method (SR11) aligns economic incentives with BIM adoption. Establishing a Bi-annual training/workshop by professional bodies (SR13) emphasises ongoing education and industry collaboration.

Establishing supportive infrastructure for BIM adoption. This category involves strategies aimed at creating an enabling environment for BIM adoption. Creating an enabling environment within the industry (SR5) emphasises the need for a supportive industry culture. Increasing awareness among professionals and stakeholders (SR1) aligns with the importance of informed decision-making. Creating easy access to BIM software (SR3) addresses the practical aspects of software availability. Affordable procurement of BIM software (SR2) focuses on overcoming financial barriers. Sensitising and encouraging clients to use BIM software for their projects (SR4) emphasises the role of client demand in driving adoption.

Government policy and enforcement. This category revolves around strategies related to government policies and their enforcement. Enforcement of government policy (SR7) underscores the importance of regulatory compliance. Government policy (SR6) highlights the role of policy formulation in shaping the industry landscape.

Collectively, these strategies form a comprehensive approach to overcoming barriers and promoting BIM adoption in post-construction processes. They address aspects ranging from industry culture and education to regulatory frameworks and financial considerations. Collaborative efforts across industry stakeholders, government bodies and professional organisations are essential for effective implementation. Academic research can play a crucial role in evaluating the impact of these strategies, identifying best practices and informing continuous improvements in adopting BIM in post-construction.

Relationship between barriers and strategies. Table S3 reveals intricate relationships among the clusters of barriers and strategies, offering valuable insights into the dynamics of BIM adoption in post-construction. Firstly, promoting BIM awareness and skill development exhibits a strong positive correlation (0.887) with establishing supportive infrastructure, emphasising the cohesiveness between strategies that foster skills and awareness and those focused on creating an enabling industry environment. Moreover, establishing supportive infrastructure shows a notable positive correlation (0.721) with government policy and enforcement, underscoring the interconnectedness of strategies promoting a supportive environment with those emphasising regulatory frameworks. This alignment suggests an industry culture conducive to BIM adoption aligns with effective government policies and enforcement.

Furthermore, the government policy and enforcement cluster significantly positively correlates with technological integration (0.949) and regulatory compliance and expertise (0.606). This implies that effective government policies and their enforcement are closely associated with advanced technological integration and regulatory compliance within the industry. Technological integration, in turn, exhibits substantial positive correlations with the data and information infrastructure (0.851) and regulatory compliance and expertise (0.902), emphasising the interrelatedness of technological advancements with robust data infrastructure and regulatory compliance. Consequently, the overall examination of the relationship between the barriers and strategies indicates a significant positive correlation (0.780), emphasising the recognition that understanding barriers prompts the active development and implementation of strategies.

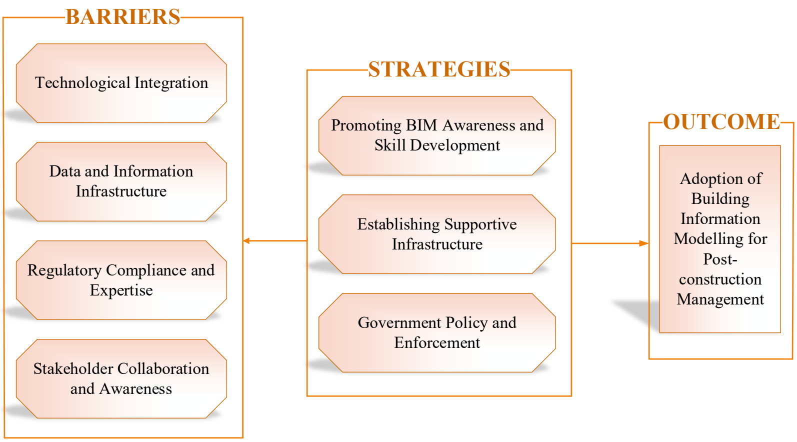
This relationship underscores the complexity and interdependence of various factors in the BIM adoption landscape. Recognising these relationships is crucial for developing comprehensive, multifaceted strategies that address barriers and promote BIM adoption across different dimensions. These findings provide valuable guidance for policymakers, industry professionals and researchers seeking to enhance BIM adoption in post-construction processes.

Discussion of results

Although the professionals perceived poor awareness as the most critical barrier towards adopting BIM for post-construction in Abuja, this result is in concordance with related literature establishing poor awareness levels in Nigeria (Ikediashi *et al.*, 2022; Okwe *et al.*, 2022), it negates the study of Ajayi (2022) establishing a low level of awareness. The study of Bello and Ayegba (2023) established a high level of awareness among the professionals in Abuja; however, the usage level of BIM tools for operations is critically low as professionals still operate manually. Through their response, the professionals show that the unavailability of software is a significant barrier deterring software usage as availability can interpret usage. According to the study of Okwe *et al.* (2022), unavailability is a significant challenge inhibiting BIM adoption among Lagos professionals. While the software availability issue is ranked higher in this study, it was ranked lower in the study of Okwe *et al.* (2022), although still above the set threshold. This barrier is considered more critical to the professionals in Abuja than Lagos; therefore, this finding sheds light on providing informed and comprehensive decisions when developing overall strategies or frameworks for adopting BIM for post-construction in Nigeria to capture the peculiarities of every region to ensure effectiveness.

Difficulties in using new technologies, perception towards BIM generality and lack of technological readiness are encountered. The findings correspond with the extant studies previously carried out in Nigeria. Relatedly, the study of Ikediashi *et al.* (2022) espouses difficulty in integrating facility management technologies, significantly inhibiting the adoption of BIM at this phase. Moreso, the study of Okwe *et al.* (2022). Moreover, the criticality of poor perception of BIM among professionals agrees with Okwe *et al.* (2022) that good perception of BIM among professionals can significantly influence the acceptance of BIM. This finding consequently agrees with the findings of Shen *et al.* (2016), establishing a low level of preparedness in developing countries, which hinders efforts of implementing emerging technologies like BIM.

The developed strategies present a comprehensive and context-specific approach to overcoming the challenges of adopting BIM for post-construction in Nigeria. Without extensive literature addressing the unique considerations of the Nigerian context, these strategies offer a tailored framework to propel BIM adoption forward. Firstly, instituting training and workshops on BIM software within organisations signifies a commitment to skill development and capacity building, addressing a crucial barrier to adoption. Secondly, integrating BIM software courses into various professional exams recognises the importance of formal education in fostering a standardised understanding of BIM across diverse professional disciplines. Encouraging adoption from the grassroots, particularly in higher education institutions, aligns with a forward-looking strategy aiming to cultivate a future workforce inherently proficient in BIM. Establishing bi-annual training and workshops by professional bodies, exemplified by the IFMA, offers a structured avenue for ongoing professional development, knowledge exchange and industry-wide standards. Emphasising flexibility among industry stakeholders underscores the need for a cultural shift towards embracing innovative technologies like BIM, fostering an environment conducive to adoption. Lastly, positioning projects executed with BIM as cost-effective compared to traditional methods provides a tangible economic incentive, aligning with financial considerations and potentially driving widespread adoption. Together, these strategies present a multifaceted approach that addresses skill gaps, promotes educational integration, fosters industry collaboration, encourages cultural adaptability and provides economic incentives, collectively positioning them as integral components of a nuanced and effective framework for BIM adoption in Nigerian post-construction practices. Figure 2 presents a



Source(s): Authors concept

Figure 2. Strategic adoption framework for BIM in post-construction

Strategic Adoption Framework for BIM in Post-Construction, showing the integration of the strategies to mitigate the barriers, thereby leading to BIM adoption.

Conclusion

This study delves into the barriers and strategies towards adopting BIM for post-construction in Nigeria, leveraging insights from registered professionals registered with IFMA. Through their training, these professionals are well-positioned to offer nuanced perspectives on the intricate barriers and strategies associated with BIM adoption in Nigeria's post-construction context. The research in this area is notably overdue, lending a unique significance to this study. The barriers identified are pivotal in understanding the hindrances to BIM adoption in Nigeria, which, in turn, have profoundly impacted traditional building management methods. These traditional approaches often lead to higher maintenance costs and accelerated deterioration rates. This study underscores the efficacy of a training and workshop-oriented approach to expedite the adoption of BIM for post-construction, positioning it as the most effective strategy. Consequently, the relationship between the barriers and strategy shows the need for developing comprehensive strategies that address barriers and promote BIM adoption across various scopes.

Implications

This study contributes theoretically by shedding light on the barriers and strategies to adopt BIM for post-construction in Nigeria. It enhances understanding of how contextual factors unique to Nigeria impact the adoption of advanced construction management technologies. This theoretical insight can serve as a foundation for future research in similar contexts, providing a framework for analysing technology adoption in the project life-cycle. From a practical standpoint, the findings of this study offer valuable guidance to practitioners in the Nigerian AECO industry. Professionals can use the identified barriers and recommended strategies as a roadmap for integrating BIM into their post-construction practices. This can improve efficiency, cost savings and better asset performance, benefiting construction companies and facility managers.

Recommendations, future studies focus and limitations

To address the identified barriers, such as limited knowledge and awareness, stakeholders must prioritise substantial investment in comprehensive BIM training and workshops. Collaborative initiatives are needed between professional associations, educational institutions, and government bodies to raise awareness about BIM's tangible benefits post-construction. Government support is pivotal, and policymakers should consider implementing regulations and incentives to encourage BIM use in projects. As this study signifies a significant step in understanding BIM adoption in Nigeria, future research directions are crucial. Longitudinal analyses are needed to track the trajectory of BIM adoption over time, considering its evolving impact and challenges. Cross-country comparisons can offer valuable insights, while in-depth case studies should be conducted to provide practical insights into overcoming barriers. User experience research can further delve into the human aspects of adoption and policy analysis should assess the effectiveness and potential limitations of government policies. However, it is essential to acknowledge the study's limitations, including potential biases in the sample and scope constraints. Future research should aim for more diverse samples, consider a broader range of contextual factors and account for potential biases in advancing the understanding of BIM adoption in the Nigerian AECO industry.

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Appendix

S/N	Barriers	Sources
BR1	Lack of awareness	Bello *et al.* (2022), McAuley *et al.* (2017)
BR2	Lack of expertise within the organisations/Field	Kim *et al.* (2016), Azhar (2011)
BR3	Lack of collaboration among stakeholders	Hamma-Adamma (2020), Hjelseth (2017)
BR4	Lack of client demand	Ademci and Gundes (2018), Enshassi *et al.* (2016)
BR5	Ambiguity in model information update	Ademci and Gundes (2018), Eastman *et al.* (2011)
BR6	Inadequacy of mode data	Chioma *et al.* (2020), Hamma-Adama (2020)
BR7	Interoperability issues	Edirisinghe *et al.* (2016), Azhar (2011)
BR8	Non-existence of contractual and legal framework for BIM implementation	Ademci and Gundes (2018), McAuley *et al.* (2017)
BR9	Difficulties in using new technologies	Ademci and Gundes (2018), Walasek and Barszcz (2017)
BR10	Unavailability of BIM requirements	Arunkumar *et al.* (2018), Edirisinghe *et al.* (2016)
BR11	Limited studies on BIM and post-construction inter-relationship	Bello and Ayegba (2023), Akerele and Etiene (2016)
BR12	Poor acceptance levels and resistance to change among stakeholders	Walasek and Barszcz (2017), Hosseini *et al.* (2018)
BR13	Lack of technological readiness	Ademci and Gundes (2018), Kim *et al.* (2016)
BR14	Insufficient awareness levels for BIM and post-construction integration benefits	Bello *et al.* (2022), Olapade and Ekemode (2018)
BR15	Perception towards BIM in generality	Ademci and Gundes (2018), Arayici *et al.* (2011)
BR16	Inadequate regulatory procedures	Mustaffa *et al.* (2017), Eastman (2011)
BR17	Lack of relevant legislation	Valappil and Saleeb (2016), Ismail *et al.* (2017)
BR18	High investment cost	Aizat *et al.* (2019), Olanrewaju *et al.* (2022)
BR19	Return on investment (ROI) issues	Bello and Ayegba (2023), Walasek and Barszcz (2017)
BR20	Lack of infrastructure	Akerele and Etiene (2016), Arayici *et al.* (2011)
BR21	Absence of benchmark for quality	Ullah *et al.* (2019), Eastman *et al.* (2011)
BR22	Software availability issues	Tan *et al.* (2019), Ahmad *et al.* (2018)
BR23	Lack of training and skills	Liao and Ai Lin Teo (2018), Sun *et al.* (2017)

Source(s): Authors' compilation

Table S1. BIM post-construction barriers

Table S2.
Barriers and strategies rotation

Barriers	Cluster 1	2	3	4	% of variance	Cumulative %	Clusters	Strategies	Cluster 1	2	3	% of variance	Cumulative %	Cluster
BR9	0.736				18.452	18.452	Technological integration	SR15	0.856			31.690	31.690	Promoting BIM awareness and skill development
BR1	0.730							SR12	0.809					
BR13	0.675							SR10	0.808					
BR22	0.650							SR14	0.787					
BR15	0.650							SR9	0.783					
BR19	0.629							SR8	0.726					
BR12	0.610							SR11	0.708					
BR8	0.569							SR13	0.650					
BR6		0.790			16.601	35.053	Data and information infrastructure	SR5		0.732		14.530	46.220	Establishing supportive infrastructure
BR4		0.777						SR1		0.718				
BR21		0.727						SR3		0.629				
BR7		0.698						SR2		0.559				
BR5		0.691						SR4		0.513				
BR20		0.523						SR7			0.810	11.341	61.560	Government Policy and Enforcement
BR16			0.762		16.311	51.364	Regulatory compliance and expertise	SR6			0.749			
BR2			0.747					Extraction method: Principal component analysis. Rotation Method: Varimax with Kaiser normalisation						
BR23			0.738					a. Rotation converged in 4 iterations						
BR18			0.723					Kaiser-Meyer-Olkin measure of sampling adequacy				0.769		
BR3				0.789	5.952	57.316	Stakeholder collaboration and awareness	Bartlett's test of sphericity			Approx. Chi-square			826.805
BR17				0.701									df	105
BR11				0.683									Sig	0.000
BR14				0.640										
BR10				0.582										

Extraction method: principal component analysis. Rotation method: Varimax with Kaiser normalisation
a Rotation converged in 6 iterations

Kaiser-Meyer-Olkin measure of sampling adequacy		0.779
Bartlett's test of sphericity	Approx. Chi-square	1420.005
	Df	253
	Sig	0.000

Source(s): Authors' analysis

Table S3. Barriers and strategies relationship

Barriers and strategies clusters relationship	Promoting BIM awareness and skill development	Establishing supportive infrastructure	Government policy and enforcement	Technological integration	Data and information infrastructure	Regulatory compliance and expertise	Stakeholder collaboration and awareness
Promoting BIM awareness and skill development	1						
Establishing supportive infrastructure	0.887 0.619	1					
Government policy and enforcement	0.000 0.000	0.721* 0.000	1				
Technological integration	0.549** 0.004	0.682 0.000	0.949** 0.004	1			
Data and information infrastructure	0.813 0.000	0.631** 0.000	0.851** 0.000	0.430** 0.000	1		
Regulatory compliance and expertise	0.882 0.000	0.762 0.000	0.606* 0.013	0.902 0.000	0.866 0.000	1	
Stakeholder collaboration and awareness	0.781 0.000	0.712** 0.000	0.513** 0.000	0.833** 0.000	0.566** 0.000	0.722** 0.000	1

**Correlation is significant at the 0.01 level (2-tailed)
*Correlation is significant at the 0.05 level (2-tailed)

Barriers and strategies relationship	Barriers	Strategies
Barriers	1	
Strategies	0.780**	1

Note(s): **Correlation is significant at the 0.01 level (2-tailed)
Source(s): Authors' analysis