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ASSESSMENT OF THE INTEGRATION OF BUILDING INFORMATION MODELLING (BIM) AND DIGITAL TWIN TECHNOLOGIES FOR REAL-TIME FACILITIES MANAGEMENT DECISION-MAKING IN ANAMBRA STATE, NIGERIA

Cynthia Oluchi Okoye[1*] and Prof. Chinelo Priscilla Igwe[2]

[1*, 2]Department of Estate Management, Nnamdi Azikiwe University, Awka

[*]**Corresponding Author's Email:** cynthiaoluchi2020@gmail.com

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ABSTRACT

Facilities management (FM) on a global scale is evolving from a reactive, paper-based approach to a proactive, data-driven methodology facilitated by Building Information Modelling (BIM) and Digital Twin (DT) technologies. However, this evolution remains largely unrecorded in southeastern Nigeria. This study assessed the integration of BIM and DT technologies for real-time decision-making in FM across Awka, Onitsha, and Nnewi in Anambra State. A mixed-methods approach was employed, which included a census survey of 172 registered Estate Surveyors and Valuers, yielding 158 valid responses, alongside semi-structured interviews with 15 technical key informants. The analysis utilized descriptive statistics, Relative Importance Index, Pearson correlation, and multiple regression, conducted with SPSS Version 26. The results indicated a superficial level of awareness and minimal utilization of BIM-DT technologies, yet a statistically significant positive correlation ($r = 0.613$, $p < .001$) was found between the adoption of these technologies and the efficiency of FM decision-making. Furthermore, barriers related to financial, infrastructural, regulatory, and technical literacy were significant predictors of implementation outcomes ($R^2 = 0.299$, $p < .001$). The study advocates for coordinated policy efforts, capacity-building initiatives, and infrastructure improvements to bridge the identified gap between awareness and action.

Keywords: *Building Information Modelling; Digital Twin; Facilities Management; Technology Adoption; Anambra State.*

1.0 INTRODUCTION

Contemporary facilities management (FM) increasingly depends on digital technologies to improve operational efficiency, maintenance planning, and asset performance (Ebiloma, Aigbavboa, and Anumba, 2023). In the past, facility managers relied on manual records, paper drawings, and fragmented information systems, a method that has proven insufficient for buildings that are becoming more intricate and data-driven. Among the digital solutions that address this shortcoming, Building Information Modelling (BIM) and Digital Twin (DT) technologies stand out. BIM provides a digital representation of the physical and functional attributes of a facility throughout its life cycle (Altwassi, Aysu, Ercoskun, and Abu Raed, 2024), whereas Digital Twin technology enhances this static model by connecting it to real-time sensor data from the physical asset, allowing for continuous synchronization between the actual and virtual environments (Hosamo, Imran, Cardenas-Cartagena, Svennevig, Svidt, and Nielsen, 2022). Collectively, BIM and DT represent a significant shift from reactive to proactive, and potentially prescriptive, facility management (Radzi, 2023).

The integration of BIM and DT has gained significant momentum in advanced economies such as the United Kingdom, Singapore, and the United States, where national policies and smart-city initiatives have driven their adoption. In sub-Saharan Africa, the uptake remains in its early stages, with South Africa at the forefront of BIM standardization and only a few isolated pilot projects emerging in other regions (Ariono, Wasesa, and Dhewanto, 2022; Pinti, Codinhoto, and Bonelli, 2022). In Nigeria, particularly, the primary challenges hindering the adoption of Building Information Modeling (BIM) among construction and facilities management (FM) professionals include a lack of awareness, the absence of governmental policies, and high implementation costs (Olanrewaju, Chileshe, Babarinde, and Sandanayake, 2020). Even in instances where there is awareness of BIM, its utilization in post-construction FM operations remains limited (Bello and Ayegba, 2025). The disparity in Digital Twin (DT) technology is even more significant: Ebiloma et al. (2023) highlight the near-total lack of structured maintenance documentation in Nigerian facilities, which is a fundamental barrier since DT systems rely on well-organized historical asset data to provide predictive insights.

In Anambra State, this technological deficiency is exacerbated by an FM landscape that is predominantly reactive, underfunded, and technologically underdeveloped (Osuya, Adenuga, and Oshodi, 2023). Although the state's Digital Economy Strategy (2022-2030) prioritizes technology-driven governance and smart infrastructure (Innovation Anambra, 2025), there has been no documented initiative specifically aimed at promoting BIM or DT adoption within the FM sector. Facilities in the three major urban centers of the state, Awka, Onitsha, and Nnewi, continue to be managed through disjointed, manual, and reactive methods that hinder continuous data feedback and predictive analytics. Moreover, there is a lack of peer-reviewed research that has empirically investigated the awareness, adoption, operability, and barriers to the integration of BIM and DT within this tri-city built environment, a gap that this study seeks to fill.

This research holds significant theoretical and practical implications. While BIM is widely acknowledged for its contributions to design and construction, its application in FM post-construction remains insufficiently examined, especially in developing regions. Therefore, this

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study addresses a critical knowledge gap by exploring how BIM data environments can be integrated with real-time DT systems to enhance operational decision-making. In practical terms, the results provide facility managers with evidence regarding how BIM-DT can facilitate predictive maintenance and performance monitoring. Additionally, it offers estate developers and property owners guidance on the long-term cost advantages of early BIM-DT integration, while also supplying public agencies and policymakers with a foundational evidence base for digital transformation strategies within the built environment. The scope of the study is geographically confined to Awka, Onitsha, and Nnewi, focusing solely on the application of BIM and DT in post-construction, real-time facilities management decision-making, intentionally omitting the design and construction phases of BIM implementation.

The aim of this study is to evaluate the integration of BIM and Digital Twin technologies in improving real-time facilities management decision-making in Anambra State. The specific objectives are to:

a. Evaluate the current level of BIM and DT technology adoption among facilities management professionals in Anambra State;
b. Examine global best practices in BIM and DT adoption for facilities management to establish benchmark standards for contextual comparison;
c. Assess the operability of BIM and DT technologies in facilitating real-time, data-driven facilities management in Anambra State;
d. Identify the obstacles hindering the adoption and integration of BIM and DT technologies in facilities management practices in Anambra State; and
e. Analyze the advantages of incorporating BIM and DT technologies into facilities management practices in the study area.

In alignment with these objectives, the study tests two hypotheses: H_{01}, which posits that there is no significant relationship between the adoption of BIM-DT technologies and the efficiency of facilities management decision-making; and H_{02}, which asserts that the challenges impacting BIM-DT adoption do not significantly affect their implementation in facilities management.

2.0 LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 Building Information Modelling and Digital Twin Technology

Building Information Modelling (BIM) is defined as a digital representation of a building that includes detailed information about its physical structure and operational components. In contrast to traditional two-dimensional drawings, BIM integrates architectural, structural, mechanical, and electrical data into a unified digital platform, utilizing software such as Autodesk Revit, ArchiCAD, and Bentley OpenBuildings (Altwassi et al., 2024). Initially created to enhance design and construction processes, BIM has gradually transformed into a resource for facility management, serving as a database of building information that aids in maintenance, operations, and performance monitoring (Visartsakul and Damrianant, 2023). Nevertheless, as buildings grow increasingly complex, there is a rising demand for systems that provide real-time operational data instead of static models, leading to the emergence of the Digital Twin concept.

A Digital Twin is a virtual representation of a physical structure that continuously gathers real-time data from the actual facility through embedded sensors that monitor various parameters, including temperature, energy consumption, and occupancy. To create a Digital Twin, a BIM model is uploaded to a platform such as Autodesk Tandem, Bentley iTwin, Siemens Building X, IBM Maximo, or Microsoft Azure Digital Twins, and is connected to physical Internet of Things (IoT) sensors installed within the building. These sensors transmit real-time data to the cloud-hosted model via Wi-Fi or Bluetooth gateways (Eneyew, Capretz, and Bitsuamlak, 2022). This sets BIM apart, as it is a digital drawing enriched with data, while a Digital Twin represents a dynamic system capable of real-time signaling, predictive alerts, and simulation (Deng, Menassa, and Kamat, 2021). According to Hosamo et al. (2022), the synergy of BIM and DT establishes the groundwork for a smart, data-driven approach to building operations, amalgamating geometric, semantic, and sensor data to enable immediate responses to evolving conditions, while Visartsakul and Damrianant (2023) note that this integration enables simulation of 'what-if' scenarios that equip managers to evaluate strategies prior to physical implementation.

2.2 Global Best Practices and the Nigerian Context

In the United Kingdom, the Government Construction Strategy established in 2011 introduced the first national BIM mandate globally, which required all centrally procured public sector projects to adopt BIM Level 2 by April 2016. Similarly, Singapore's Building and Construction Authority mandated BIM for architectural works on buildings exceeding 5,000 m² starting in 2010, gradually expanding this requirement to include structural and mechanical, electrical, and plumbing works. These policy-driven initiatives spurred rapid, industry-wide adoption and fostered a self-sustaining ecosystem of BIM education, software standardization, and professional development. A review by Wijeratne, Gunarathna, Yang, Wu, Hampson, and Shemery (2023) of 33 real-world BIM-FM enablement cases revealed that the integration of BIM with Computerized Maintenance Management Systems (CMMS) and Computer-Aided Facilities Management (CAFM) platforms was the most commonly adopted approach worldwide, occurring in 21 out of the 33 cases. The success of this integration was heavily reliant on standardized information handover protocols, such as COBie data drops at practical completion.

On the other hand, the context of Anambra State is marked by a complete lack of any comparable policy framework. More broadly in Nigeria, Ikediashi, Ansa, Ujene, and Akoh (2022) assessed the barriers to BIM adoption for FM through 135 valid responses from three Nigerian cities. Utilizing exploratory factor analysis, they identified significant latent barrier clusters, including deficiencies in technology and infrastructure, a lack of awareness, and the absence of regulatory frameworks. In Lagos, research by Okwe, Olanrewaju, Heckman, and Chileshe (2023) indicated that even within the most professionally engaged FM community in Nigeria, awareness and acceptance of BIM-FM integration were critically lacking, with six out of ten identified barriers rated as critical, notably including the lack of a contractual and legal framework for BIM implementation. Similarly, Bello and Ayegba (2025), studying IFMA-registered professionals in Abuja, found that BIM application in post-construction FM operations was significantly low despite relatively high general awareness, demonstrating that awareness alone does not translate into adoption without organisational capacity and policy support.

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2.3 Theoretical Framework

This research is based on three interrelated theories. The Technology Acceptance Model (TAM), introduced by Davis in 1989, posits that an individual's intention to utilize a technology is influenced by Perceived Usefulness and Perceived Ease of Use, with Perceived Usefulness generally being the more significant predictor of actual usage behavior. The Diffusion of Innovation (DOI) Theory, as articulated by Rogers in 2003, views adoption not merely as a binary occurrence but as a dynamic and time-sensitive process influenced by an innovation's relative advantage, compatibility, complexity, and observability as it spreads through a social system. The Resource-Based View (RBV), proposed by Barney in 1991, adds an organizational capability perspective, asserting that a firm's ability to adopt and maintain technologies such as BIM-DT is contingent upon its possession of resources that are valuable, rare, difficult to imitate, and non-substitutable. When applied collectively, TAM elucidates the individual cognitive and attitudinal factors driving adoption, DOI clarifies the social and temporal dynamics of diffusion among facilities management (FM) professionals, and RBV accounts for the variations in structural readiness among FM organizations to adopt and sustain BIM-DT systems, thereby offering a theoretically integrated, multi-faceted perspective for this study.

2.4 Facilities Management in the Built Environment

Facilities management involves the comprehensive management of the workplace and its supporting infrastructure to improve the efficiency of an organization's core functions, which includes maintenance management, space management, health and safety, and sustainability performance, as noted by Opoku and Lee in 2022. In a mixed-method review of sustainable FM practices, Okoro (2023) highlights that facilities management in developing economies tends to be largely reactive, characterized by unplanned, corrective maintenance actions rather than the planned, predictive maintenance strategies that the integration of BIM-DT aims to facilitate. This reactive orientation is directly relevant to the Anambra State context, where Osuya et al. (2023) similarly found that maintenance management practice in government-owned institutions is largely unplanned and underfunded, a condition that both motivates and constrains the digital transformation this study investigates: it motivates it, because the inefficiencies of reactive FM are precisely what BIM-DT promises to resolve, and it constrains it, because organisations operating reactively typically lack the structured maintenance documentation and data governance foundations on which Digital Twin systems depend.

2.5 Empirical Review and Gap in Literature

Olanrewaju et. al (2020) conducted a survey involving 182 Nigerian construction professionals and discovered that only three out of fourteen identified barriers were deemed critical: limited studies and knowledge, insufficient government policy, and high implementation costs, with knowledge deficiency being ranked higher than cost as the foremost barrier. In a review by Opoku, Perera, Osei-Kyei, Rashidi, Bamdad, and Famakinwa (2023) of 40 peer-reviewed studies concerning barriers to Digital Twin adoption in construction published between 2017 and 2022, it was noted that no African country was represented in the reviewed literature, with low knowledge and low technology acceptance being the most commonly reported barriers on a global scale. Signorini and Pomè (2025), in their assessment of Digital Twin readiness within the Italian Facility Management (FM) market through a participatory action research approach, found that while

67.3% of FM operators surveyed considered Digital Twin as one of the three technologies likely to have the most significant impact on FM in the next five years, less than 12% of the organizations surveyed reported any active deployment of Digital Twin, suggesting that even in a digitally advanced European market, the adoption of Digital Twin in FM is still in its early stages. At the level of systematic review, Abideen et al., (2022) adhered to the PRISMA protocol across three multidisciplinary databases and, from an initial selection of 1,026 articles, synthesized 167 peer-reviewed studies regarding the integration of Building Information Modeling (BIM) into the global operation and maintenance lifecycle phase. Their review revealed that the operation and maintenance phase constitutes approximately 60% of the total building lifecycle cost, yet it remains the least systematically supported by BIM-enabled tools globally, with maintenance and repair, energy management, and safety management being the most frequently investigated applications in Facility Management. This finding supports the fundamental premise of the current study: that the post-construction phase, despite its critical importance in the lifecycle, is still relatively neglected in BIM research and practice. This issue is particularly pronounced in the context of Nigeria and Anambra State compared to the predominantly Western literature reviewed.

The review identifies substantial gaps that this study aims to fill. Firstly, existing research on BIM-FM barriers in Nigeria has primarily focused on Lagos and Abuja, with no peer-reviewed empirical studies investigating the awareness, adoption, and barriers faced by estate surveyors and valuers in Anambra State or similar southeastern Nigerian regions. Secondly, although barriers to DT adoption have been examined on a global scale, the complete lack of African contexts in this literature (Opoku et al., 2023) indicates that DT-FM adoption in sub-Saharan Africa remains largely unexplored. Thirdly, there has been no study that has statistically analyzed the relationship between BIM-DT adoption and the efficiency of FM decision-making, nor the predictive impact of adoption barriers on implementation outcomes within any Nigerian FM context. This study specifically addresses these identified gaps.

3.0 METHODOLOGY

This research employed a mixed-methods approach, integrating a quantitative structured questionnaire survey with qualitative semi-structured interviews, conducted simultaneously, analyzed independently, and synthesized during the interpretation phase. This methodology was selected because the study's aims necessitated both statistical evaluation of awareness, barriers, and the relationship between adoption efficiency, as well as experiential understanding of the contextual factors influencing adoption behavior. A cross-sectional survey design was utilized for the quantitative aspect, which is suitable for capturing the existing state of professional knowledge and practice at a specific moment in time.

The research was carried out in Anambra State, located in southeastern Nigeria, concentrating on its three main urban centers: Awka (the administrative and educational center), Onitsha (the commercial center and one of West Africa's largest trading cities), and Nnewi (the industrial center, often referred to as the 'Japan of Africa' due to its concentration of manufacturing). Together, these three cities account for over 80% of the state's active facilities management operations across administrative, commercial, and industrial sectors, offering a statistically representative cross-section of the state's built environment (Innovation Anambra, 2025).

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The study population consisted of facilities management professionals in Anambra State, primarily registered Estate Surveyors and Valuers (ESVs) listed in the Nigerian Institution of Estate Surveyors and Valuers (NIESV) Anambra State Branch register, totaling 172 as of 2026. Given the relatively small and finite population, a total enumeration (census) method was employed, distributing 172 questionnaires proportionally among Awka, Onitsha, and Nnewi. Additionally, a qualitative sample of 15 key informants, with five selected from each city, was purposively chosen from BIM software engineers, ICT specialists, and technical building services professionals possessing the technical expertise and readiness to implement BIM-DT systems in facilities management. This selection was made because a thorough evaluation of BIM-DT operability necessitated insights from practitioners with the requisite technical knowledge to assess the feasibility, requirements, and implementation pathway for these technologies, rather than requiring prior hands-on experience operating a live system.

Data collection involved a structured questionnaire (quantitative) and a semi-structured interview guide (qualitative). The questionnaire included Section A, which gathered biographical and professional information, and Sections B to D, which utilized a five-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree) to evaluate awareness and adoption of BIM-DT (Section B), barriers to adoption categorized into four areas: digital infrastructure, technical literacy and human capital, policy and regulatory, and financial and organizational barriers (Section C), as well as perceived benefits and professional acceptance (Section D). The questionnaires were distributed through personal delivery and Google Forms. The interview guide was utilized with the fifteen key informants, focusing on contextual enablers and barriers to BIM-DT adoption and their perceptions of operability; the interviews were audio-recorded and transcribed verbatim for thematic analysis.

The face validity of the questionnaire was confirmed through an evaluation by the researcher's supervisor and two seasoned academics in estate and facilities management. Qualitative validity was achieved via member checking and triangulation with survey data. The reliability of the instrument was evaluated using Cronbach's Alpha, with a pre-established acceptable threshold of 0.70, following a pilot test conducted with ten ESVs who were not included in the main sample.

Quantitative data were analyzed using SPSS Version 26, employing descriptive statistics (frequencies, percentages, means, and standard deviations) to fulfill Objective One. The Relative Importance Index ($RII = \Sigma W / (A \times N)$, where W represents the weight assigned by each respondent, A denotes the maximum weight on the scale, and N indicates the total number of respondents) was utilized to rank barriers under Objective Four. Additionally, Pearson correlation analysis was performed to test H_{01}, and multiple linear regression was applied to test H_{02}. The qualitative data obtained from the interviews were analyzed thematically through inductive coding and were cross-verified with the quantitative findings to enhance the contextual validity of the study's conclusions.

4.0 RESULTS AND DISCUSSION

4.1 Questionnaire Distribution and Response Rate

Of the 172 questionnaires distributed across the three study cities following the total enumeration method, 158 valid responses were retrieved, yielding a response rate of 91.9% (rounded to 92%), a rate high enough to support robust generalisation of findings within the sampled population. Fourteen instruments were excluded due to non-return or excessive incompleteness.

Table 1: Distribution and Return of Questionnaires

City	Distributed	Retrieved	Excluded	Valid for Analysis
Awka	68	63	5	63
Onitsha	62	57	5	57
Nnewi	42	38	4	38
Total	172	158	14	158

Source: Field Survey (2026)

4.2 Demographic Characteristics of Respondents

The demographic profile revealed a sample characterized by professional experience, high educational attainment, and a broad representation across the three cities involved in the study. Male participants made up the majority at 57.6%, which aligns with the traditionally male-centric nature of the Nigerian estate surveying profession; however, the 42.4% representation of females indicates an increasing involvement of women in the field. The predominant age group was 41-50 years, accounting for 38.6% of respondents, while those with 11-20 years of professional experience represented the largest segment at 34.8%. Notably, 85.4% of the sample had six or more years of experience, suggesting that the findings of the study are based on substantial professional insight. In terms of education, 43.0% of respondents held a Bachelor of Science degree as their highest qualification, and 40.5% possessed a Master of Science degree, with a total of 48.1% having a postgraduate qualification. Geographically, the respondents were sourced from Awka (39.2%), Onitsha (36.1%), and Nnewi (24.7%), reflecting the distribution of registered practitioners in these cities. Furthermore, Property Management (32.9%) and Facilities Management (32.3%) emerged as the most prevalent primary areas of practice, ensuring that the dataset effectively captured the viewpoints of practitioners with direct operational experience in facilities management.

Table 2: Summary of Demographic Characteristics of Respondents (N = 158)

Variable	Category	Frequency	Percentage (%)
Gender	Male	91	57.6
	Female	67	42.4
Age	Below 30	14	8.9
	31-40	53	33.5
	41-50	61	38.6

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	Above 50	30	19.0
Education	OND/HND	11	7.0
	B.Sc	68	43.0
	M.Sc	64	40.5
	PhD	12	7.6
	Others	3	1.9
Experience	1-5 years	23	14.6
	6-10 years	47	29.7
	11-20 years	55	34.8
	Above 20 years	33	20.9
City of Practice	Awka	62	39.2
	Onitsha	57	36.1
	Nnewi	39	24.7
Practice Area	Facilities Management	51	32.3
	Valuation	37	23.4
	Property Management	52	32.9
	Others	18	11.4

Source: Field Survey (2026)

Instrument reliability, assessed prior to substantive analysis, confirmed strong internal consistency across all sections, with the overall instrument returning a Cronbach's Alpha of 0.917, categorised as excellent and well above the 0.70 acceptability threshold established a priori (Table 3).

Table 3: Cronbach's Alpha Reliability Coefficients

Section	No. of Items	Cronbach's Alpha (α)	Interpretation
B: Awareness and Adoption	15	0.889	Good
C: Barriers to Adoption	16	0.912	Excellent
D: Benefits and Acceptance	11	0.903	Excellent
Overall Instrument	42	0.917	Excellent

Source: SPSS Output (2026)

4.3 Adoption Level of BIM and Digital Twin Technologies (Objective One)

A mean score of 3.50 or higher was interpreted as an indication of agreement, whereas scores falling below 3.50 signified disagreement. The general awareness of Building Information Modeling (BIM) as a technology for Facilities Management (FM) was moderate, with a mean score of 3.80; however, this awareness was found to be superficial. Familiarity with specific BIM tools, such as Autodesk Revit and ArchiCAD, was significantly lower, with a mean score of 3.01. Awareness of international standards like IFC and COBie was even lower, with a mean of 2.79. Furthermore, respondents expressed strong disagreement regarding the adequacy of BIM awareness promotion within the profession in Anambra State, reflected in a mean score of 2.34. In comparison, awareness of Digital Twin technology consistently lagged behind BIM awareness across all assessed items, with no item in this subsection achieving a mean score above 3.12. Notably, the item evaluating whether Digital Twin is adequately promoted within the Nigerian FM professional community recorded the lowest mean in the entire subsection at 2.16.

Importantly, the utilization data indicated that both BIM and Digital Twin technologies remain aspirational rather than operational within the FM sector of Anambra State. None of the utilization items achieved a mean score exceeding 2.23. Only 17.1% of respondents reported currently employing BIM-based tools in their FM practices, while merely 13.3% indicated organizational adoption of BIM for any FM function. Also, the utilization of Digital Twin technology recorded the lowest mean in the entire study at 1.82, with only 7.6% of respondents reporting any active use of Digital Twin on current projects. This significant gap between conceptual awareness and practical application highlights the central empirical finding of the study: a pronounced awareness-action gap that necessitates bridging through structured training, policy mandates, and demonstration projects.

4.4 Operability of BIM-DT for Real-Time FM Decision-Making (Objective Three)

Operability, defined as a combination of effectiveness, efficiency, usability, practicality, and sustainability, revealed a contradictory empirical scenario. Respondents showed strong agreement regarding the potential operability of BIM-DT, with all benefit items in Section D1 yielding means between 4.08 and 4.18. However, the actual operability demonstrated in current practice was virtually nonexistent, as evidenced by the near-zero utilization scores mentioned earlier. This trend aligns with the Technology Acceptance Model's differentiation between Perceived Usefulness, which was notably high in this sample, and Actual System Use, which was lacking. Qualitative interviews further corroborated this observation: informants consistently indicated that the necessary infrastructural conditions for operability, such as reliable broadband, a stable power supply, IoT-enabled building infrastructure, and adequately trained technical personnel, are not yet sufficiently developed in any of the three study cities to support a viable Digital Twin FM platform. This suggests that achieving operability necessitates not only the deployment of technology but also the simultaneous development of an enabling infrastructure and a supportive human-capital ecosystem.

4.5 Barriers to BIM-DT Adoption and Integration (Objective Four)

Sixteen barrier items categorized into four groups, including digital infrastructure, technical literacy and human capital, policy and regulatory, and financial and organizational barriers, were

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evaluated using the Relative Importance Index. Table 4 displays the ten highest-ranked barriers overall. The unreliable power supply was identified as the most significant barrier (RII = 0.862), closely followed by the high costs associated with BIM-compatible hardware and software, as well as the substantial initial expenses of BIM-DT implementation, both of which were tied at RII = 0.852. Inadequate financial resources within FM firms (RII = 0.844) and a lack of sufficient BIM-DT training among professionals (RII = 0.838) completed the top five barriers, while the absence of a national BIM mandate in Nigeria was ranked sixth overall (RII = 0.837).

Table 4: Composite Ranking of Leading Barriers to BIM-DT Adoption (RII)

Rank	Barrier	Category	Mean	RII
1	Unreliable power supply negatively affects deployment of cloud-based BIM-DT systems	Digital Infrastructure	4.31	0.862
2	High cost of BIM-compatible hardware and software limits adoption	Digital Infrastructure	4.26	0.852
3	High initial cost of BIM-DT implementation is prohibitive for FM organisations	Financial/Organisational	4.26	0.852
4	FM firms in Anambra State lack adequate financial resources to invest in BIM-DT	Financial/Organisational	4.22	0.844
5	Insufficient BIM-DT training among FM professionals	Technical Literacy	4.19	0.838
6	Absence of a national BIM mandate in Nigeria	Policy/Regulatory	4.18	0.837
7	Lack of BIM standards specific to the Nigerian FM context	Policy/Regulatory	4.14	0.828
8	Absence of IoT-enabled building infrastructure limits DT implementation	Digital Infrastructure	4.11	0.822
9	Government building regulations do not encourage BIM-DT compliance	Policy/Regulatory	4.11	0.822
10	Inadequate broadband internet connectivity	Digital Infrastructure	4.10	0.820

Source: SPSS Output (2026).

What renders the Anambra State context distinctively challenging is the compound co-occurrence of financial, infrastructural, and regulatory barriers. Whereas Lagos-based studies such as Okwe et al. (2023) documented barriers concentrated in awareness and contractual frameworks, in Anambra State infrastructure deficits, particularly unreliable power and inadequate broadband, introduce an additional layer of constraint that is comparatively less pronounced in Lagos. Overall, financial, infrastructural, and regulatory categories dominated the upper half of the composite ranking, indicating that structural and systemic issues are considerably more limiting to adoption than individual attitudinal resistance, which was ranked lowest among the sixteen barriers assessed (organisational culture, RII = 0.767).

4.6 Benefits and Professional Acceptance of BIM-DT (Objective Five)

Despite minimal current utilization, respondents expressed strong, near-consensus agreement on the potential benefits of BIM-DT integration for FM decision-making, with all six items in Table 5 returning means above 4.00.

Table 5: Perceived Benefits of BIM-DT Integration for FM Decision-Making

S/N	Statement	Mean	Std. Dev.
1	BIM-DT adoption will improve the accuracy and speed of FM decision-making	4.18	0.958
2	Real-time data from DT platforms will reduce reactive maintenance	4.18	0.991
3	BIM-DT integration will significantly reduce FM lifecycle costs	4.11	0.987
4	DT-enabled monitoring will improve occupant comfort and safety	4.11	1.019
5	BIM-DT adoption will enhance energy efficiency and sustainability performance	4.08	0.981
6	Data-driven FM governance will improve accountability in building management	4.10	1.026

Source: SPSS Output (2026)

The item that recorded the highest mean throughout the study was the conditional willingness to adopt BIM-DT, provided that sufficient support is available (mean = 4.22). This was closely followed by the belief in the overall usefulness of BIM-DT for FM practice in Anambra State (mean = 4.19). In contrast, the confidence in the ease of learning and utilizing BIM-DT tools yielded a significantly lower mean (3.52), which was the lowest within the professional-acceptance subsection. This indicates that while practitioners acknowledge the benefits of BIM-DT, they have genuine concerns regarding the learning curve associated with it. Overall, these findings imply that the main obstacle to adoption in Anambra State is not rooted in attitudinal skepticism but rather in structural constraints: practitioners are eager to adopt BIM-DT and recognize its value, yet they are systematically hindered by the barriers outlined in Section 4.5.

4.7 Hypothesis Testing

H_{01} (indicating no significant relationship between BIM-DT adoption and FM decision-making efficiency) was evaluated through Pearson correlation analysis between a composite BIM-DT Adoption Score (Section B, 15 items) and a composite FM Decision-Making Efficiency Score (Section D, 11 items). Prior to the analysis, normality (Shapiro-Wilk $p = .081$ and $p = .063$ respectively), the absence of significant outliers, and linearity were confirmed.

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Table 6: Pearson Correlation Matrix (BIM-DT Adoption and FM Decision-Making Efficiency)

Variable	BIM-DT Adoption Score	FM Decision-Making Efficiency	N	p-value
BIM-DT Adoption Score	1.000	0.613	158	< .001
FM Decision-Making Efficiency	0.613	1.000	158	< .001

Source: SPSS Output (2026). N = 158, p < .001 (two-tailed).

The analysis indicated a statistically significant positive correlation between the adoption of BIM-DT and the efficiency of FM decision-making ($r = 0.613$, $t(156) = 9.581$, $p < .001$). This represents a moderate-to-strong relationship in the context of built-environment research, with the coefficient of determination ($r^2 = 0.376$) suggesting that approximately 37.6% of the variance in FM decision-making efficiency can be attributed to variations in BIM-DT adoption. Consequently, H_{01} was rejected at the 0.05 significance level, affirming that greater adoption of BIM-DT is positively and significantly linked to improved FM decision-making efficiency.

H_{02}, which posits that adoption challenges do not significantly affect implementation, was analyzed through multiple linear regression. In this analysis, the BIM-DT Implementation Outcome Score served as the dependent variable, while the four composite barrier-category scores were utilized as predictors, entered via the Enter method. The diagnostics for multicollinearity (tolerance values ranging from 0.713 to 0.881; VIF values between 1.135 and 1.402) and the Durbin-Watson statistic ($d = 1.974$) confirmed that the assumptions of the regression analysis were met.

Table 7: Regression Model Summary and ANOVA

Statistic	Value
R	0.547
R^2	0.299
Adjusted R^2	0.280
Std. Error of Estimate	0.4712
Durbin-Watson	1.974
F (4, 153)	16.317
Sig. (ANOVA)	< .001

Source: SPSS Output (2026). Predictors: (Constant), Digital Infrastructure, Technical Literacy, Policy/Regulatory, and Financial/Organisational barrier composites. Dependent variable: BIM-DT Implementation Outcome Score.

Table 8: Regression Coefficients

Predictor	B	Std. Error	Beta (β)	t	Sig.
(Constant)	4.317	0.318	-	13.576	< .001
Digital Infrastructure Barriers	-0.312	0.074	-0.289	-4.216	< .001
Technical Literacy & Human Capital Barriers	-0.274	0.081	-0.241	-3.383	.001
Policy and Regulatory Barriers	-0.198	0.079	-0.177	-2.506	.013
Financial and Organisational Barriers	-0.167	0.083	-0.148	-2.012	.046

Source: SPSS Output (2026). All predictors significant at $p < .05$.

The overall regression model demonstrated statistical significance ($F(4, 153) = 16.317$, $p < .001$), with the four barrier categories together accounting for approximately 29.9% of the variance in BIM-DT implementation outcomes ($R^2 = 0.299$; adjusted $R^2 = 0.280$). Among the predictors, Digital Infrastructure Barriers were identified as the most significant ($\beta = -0.289$, $p < .001$), followed by Technical Literacy and Human Capital Barriers ($\beta = -0.241$, $p = .001$), Policy and Regulatory Barriers ($\beta = -0.177$, $p = .013$), and Financial and Organisational Barriers ($\beta = -0.148$, $p = .046$). Each of these predictors exhibited negative coefficients, indicating that a higher perception of barrier severity correlates with a lower level of BIM-DT implementation. Consequently, H_{02} was rejected at the 0.05 significance level: the identified barrier categories, both collectively and individually, have a statistically significant negative impact on BIM-DT implementation outcomes in Anambra State.

4.8 Qualitative Insights from Key Informants

Thematic analysis of interviews conducted with 15 technical key informants revealed four themes that supported and contextualized the quantitative results. Firstly, while there is conceptual awareness, operational understanding is lacking: all informants recognized the terms 'BIM' and 'Digital Twin', yet none indicated the presence of a functional Digital Twin platform in active use. One building services engineer from Awka noted that discussions about BIM in workshops seldom translate into practical application on-site, where traditional methods such as paper and spreadsheets continue to prevail. Secondly, informants from all three cities independently identified electricity and internet connectivity as essential constraints, reflecting the highest-ranked quantitative barriers. An ICT specialist from Onitsha remarked that cloud-based Digital Twin platforms necessitate continuous power and connectivity, which the local environment cannot consistently provide. Thirdly, informants uniformly pointed out the lack of a national BIM policy or mandate as a structural barrier to organizational investment, explicitly comparing it to the UK's mandate-driven BIM Level 2 transformation. Fourthly, despite these challenges, all informants expressed a strong conditional willingness and long-term optimism regarding the adoption of BIM-DT, contingent upon training, regulatory reforms, and reduced cost burdens. This reinforces the quantitative finding that the barriers to adoption in Anambra State are primarily structural rather than attitudinal.

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These findings map onto the three theories underpinning this study. Consistent with TAM, the strong perceived-benefit scores and conditional willingness reported in Sections 4.6 and 4.8 indicate that Perceived Usefulness is not the constraint on adoption; the constraint lies elsewhere. Framed through DOI, Anambra State's professionals sit early in the diffusion curve, with awareness present but adoption behaviour not yet activated, consistent with a population still evaluating an innovation's relative advantage and compatibility rather than one resistant to it. Most directly, the dominance of financial and infrastructural barriers in both the RII rankings (Section 4.5) and the regression model (Section 4.7) supports RBV: FM organizations in the study area largely lack the valuable, rare, and difficult-to-imitate resources, capital, broadband infrastructure, and trained personnel, that BIM-DT adoption requires, regardless of individual practitioners' favourable attitudes toward the technology.

4.9 Discussion of Findings

The descriptive findings indicate that BIM and Digital Twin technologies are still in a pre-adoption phase within the FM sector of Anambra State. While there is some awareness at a conceptual level, operational knowledge, familiarity with tools, and understanding of standards are critically lacking, with actual utilization of BIM being nearly non-existent and Digital Twin effectively absent. This places Anambra State at an earlier stage in the BIM-FM adoption journey compared to global benchmarks such as the UK and Singapore, and even behind the more digitally advanced Italian FM market studied by Signorini and Pomè (2025), where DT deployment, although limited, was reported by 12% of surveyed organizations. The RII analysis corroborates that financial and infrastructural constraints are the predominant barriers in Anambra State, a trend that somewhat contrasts with evidence from Lagos (Okwe et al., 2023; Olanrewaju et al., 2020), where awareness and contractual framework deficiencies were more pronounced, suggesting that infrastructural underdevelopment presents an additional, more fundamental challenge in Anambra State.

The rejection of both null hypotheses represents the primary empirical contribution of the study. The notable positive correlation between adoption and FM decision-making efficiency (H_{01}) provides an empirical basis for investing in interventions that facilitate adoption, as even minor enhancements in adoption correlate with significant improvements in decision-making efficiency. The robust regression model (H_{02}), which identifies Digital Infrastructure Barriers as the most significant individual predictor, further suggests that investment in infrastructure is the most pressing prerequisite for advancing adoption in the study area. In conjunction with the qualitative finding of a strong conditional willingness to adopt, the results illustrate an adoption readiness profile characterized by a high perception of benefits and a strong willingness, yet constrained by severe structural barriers. This profile is fundamentally structural rather than attitudinal and should directly guide the development of policies, training, and infrastructure interventions aimed at the FM profession in Anambra State.

5.0 CONCLUSION

This study evaluated the integration of BIM and Digital Twin technologies for real-time decision-making in facilities management across the tri-city built environment of Anambra State. The findings confirm that BIM and Digital Twin technologies are still in a pre-adoption phase: while there is conceptual awareness, operational knowledge and actual usage are significantly lacking, with the effective adoption rate for Digital Twin technologies nearing zero and almost the same for BIM in current FM practices. Nevertheless, the study provides empirical evidence of a statistically significant positive correlation between the adoption of BIM-DT and the efficiency of FM decision-making. It also reveals that factors such as digital infrastructure, technical literacy, policy and regulatory issues, as well as financial and organizational barriers, both collectively and individually, influence implementation outcomes, with digital infrastructure being the most influential predictor. The adoption readiness profile of FM professionals in Anambra State, marked by a high perception of benefits, strong conditional willingness, and significant structural barriers, suggests that the primary challenge is structural rather than motivational: practitioners are eager to adopt BIM-DT and acknowledge its advantages but face systematic constraints due to financial, infrastructural, and regulatory shortcomings. Although the disparity between Anambra State's current status and global best practices is substantial, it is not insurmountable, and the noted conditional willingness among practitioners signifies a crucial opportunity for coordinated policy initiatives.

6.0 RECOMMENDATIONS

In light of the findings, the following recommendations are proposed. Firstly, the Federal Government, through the Federal Ministry of Works and Housing and the National Information Technology Development Agency, should formulate a national roadmap for BIM adoption, which includes a phased mandate for publicly procured buildings exceeding a certain floor area, inspired by the models of the UK and Singapore. Additionally, the Estate Surveyors and Valuers Registration Board of Nigeria (ESVARBON) should integrate BIM-DT competency into the annual continuing professional development requirements. Secondly, the Anambra State Government ought to enhance its current Digital Economy Strategy by initiating a state-level BIM mandate for public buildings exceeding 2,000 m², creating a subsidized BIM Resource Centre in collaboration with higher education institutions, and focusing on investments in broadband infrastructure within the most densely populated FM zones of Awka, Onitsha, and Nnewi to overcome the infrastructural challenges recognized as the primary determinant of implementation success.

In addition, the Nigerian Institution of Estate Surveyors and Valuers (NIESV) Anambra State Branch and Estate Surveyors and Valuers Registration Board of Nigeria (ESVARBON) should implement compulsory annual BIM-DT training as part of ongoing professional development, negotiate reduced institutional software licensing fees with vendors like Autodesk and Bentley Systems, and form a BIM-DT special interest group to oversee pilot projects and compile local return-on-investment case studies. Furthermore, FM organizations should embrace a gradual BIM-DT strategy that starts with the digitization of current building documentation, while individual practitioners are encouraged to utilize affordable BIM learning platforms, and smaller firms might explore consortium-based software procurement to lower costs per firm.

Lastly, academic institutions, especially the Department of Estate Management at Nnamdi Azikiwe University, should incorporate BIM and introductory Digital Twin software training into their postgraduate programs and emphasize BIM-DT FM research, including longitudinal

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adoption studies and pilot implementation assessments, to create the local evidence base that practitioners deem essential for broader adoption.

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