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An Exploratory Factor Analysis of Critical Barriers to Adopting Emerging Technologies for Quality Management in Construction Projects

Innocent Chigozie Osuizugbo[1], Chikezirim Okorafor[2], Bankole Osita Awuzie[3], and Victor Olukayode Iyanda[4]

[1&3]Department of Construction Management and Quantity Surveying, University of Johannesburg, Doorfontein Campus, Johannesburg, South Africa
[2]Department of Civil Engineering & Construction Studies Midland, Durban University of Technology Scottsville, South Africa
[4]Department of Building Technology, Bells University of Technology, Ota, Nigeria

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Abstract

This study aims to examine the barriers to the adoption of emerging technologies for quality management in construction projects. A questionnaire was designed to investigate the barriers to the adoption of emerging technologies for quality management in construction projects. Questionnaires were distributed, and 127 valid responses were elicited. Thereafter, data were analysed using descriptive and inferential statistics. The study was limited to barriers to the adoption of emerging technologies in construction quality management in Nigeria utilising a quantitative research method. The study's findings can serve as a model for tackling similar barriers in other countries in the global south. The results of the exploratory factor analysis reveal the critical barriers to the adoption of emerging technologies in construction quality management in the Nigerian construction industry can be grouped into three principal components: institutional and regulatory, organisational, and technology and industry collaboration. Understanding these findings provides a roadmap to accelerate the adoption of emerging technologies in construction quality management, leading to improved productivity, reduced rework, enhanced compliance, and sustainable industry growth.

Keywords: Adoption, Barriers, Construction projects, Emerging technologies, Quality management.

1. Introduction

The construction industry plays a significant role in a country's economic and national growth. However, the impact of this sector has been affected by productivity problems and poor project performance, as reported by Osuizugbo and Alabi (2021). Past studies have identified factors responsible for the poor construction project performance, including industry complexity, poor quality, safety issues, low productivity, slow innovation, high costs, client dissatisfaction, and skill shortages, among others (Osuizugbo & Ojelabi, 2020). Notably, poor-quality construction project delivery has been reported as the most challenging and prevalent issue within the construction industry (Luo *et al.*, 2022). Meanwhile, the sector's growth depends relatively on the quality of projects. Thus, effective management of construction projects' quality should be paramount to construction stakeholders. In other words, quality management is a key indicator which affects the value of construction projects.

More recent attention has focused on developing emerging technologies to enhance construction quality management and inspection, thereby improving the construction industry's image. Emerging technology in this study refers to innovative, cutting-edge advancements in the early stages of development that have the potential to impact society, industries, and economies significantly. Blockchain, Photogrammetry and laser scanning, Augmented Reality (AR), Building Information Modelling, Internet of Things (IoT), and

[1] Corresponding Author
Email address: innocento@uj.ac.za

Computer Vision (CV), among others, are some of the emerging technologies employed in construction quality management (Luo *et al.*, 2022; Safa *et al.*, 2015; Wang, 2008). These emerging technologies are designed to provide remarkable benefits to safety on site, quality, and productivity improvement. Adopting these emerging technologies in construction projects helps eliminate information barriers between design, prefabrication, and construction, enhances training, safety, and communication, reduces rework, enables process monitoring, preventive maintenance, site productivity assessment, real-time structural health tracking, and enhances defect detection and quality management (Luo *et al.*, 2019).

Despite many benefits that are linked with these digital tools, some challenges hinder its adoption and application in the construction sector which includes resistance to change, security concerns, high costs of hardware and software, absence of standardised guidelines and practices, lack of financial need, lack of market data for technology incorporation, and low level of knowledge among others (Tam *et al.,* 2024; Chen *et al.*, 2023; Maqsoom*et al.*, 2023; Kamaruddeen*et al.*, 2022). According to Saka and Chan (2019), the construction industry has been accused of lagging in the implementation of technology compared to other sectors. The common approach to assessing new policies and their implementation is to study the barriers/challenges they face, which typically requires identifying the root causes of resistance to change (Osuizugbo *et al.*, 2024). Using Nigeria as a representative case, these barriers are specifically significant because of economic constraints and poor quality in construction project delivery. These barriers to emerging technologies are intensified by a shortage of technical expertise and insufficient commitment to research and development, hindering the adoption of advanced quality management practices in construction projects. Secondly, high costs of software and hardware, and low knowledge of digital tools formed additional barriers. These barriers overlap with economic and regulatory factors: monetary limitations hinder the use of cutting-edge technologies, and regulatory guidelines may lack the necessary enforcement and incentives to drive the adoption and application of emerging technologies in construction quality management. Addressing these interconnected barriers is vital for enhancing the quality of construction projects in Nigeria and other nations in the global south.

Over time, several studies have been conducted on quality management. For instance, Keenan and Rostami (2019) examined the influence of quality management systems on construction performance. Wickramarachchi *et al.* (2018) studied total quality management execution in the Sri Lankan construction industry. In contrast, Wang and Wei (2020) investigated the implementation of BIM-based technology for quality management in construction engineering. Wang (2008) proposes Radio Frequency Identification (RFID)-based technology for enhancing construction quality inspection and management. The study by Safa *et al.* (2015) presented an automated approach to construction quality management that utilised advanced technologies to detect defects. The majority of these existing studies have primarily been conducted in the global North. Moreover, not all African countries have derived the same benefit from emerging technologies, including digitalisation processes (Badaru & Mphahlele, 2023). Thus, study that addresses barriers to the adoption of emerging technologies for quality management in construction projects in Nigeria are scarce. This implies that there is little to no understanding of the factors hindering the adoption of emerging technologies for quality management in construction projects in Nigeria. In addition, industry characteristics influence the adoption of emerging technologies for construction practices (Kamaruddeen *et al.*, 2022). This indicates that the adoption and application of emerging technologies for quality management practices may vary across countries. Hence, to tackle the identified gap in existing knowledge, this study aims to examine the barriers to the adoption of emerging technologies for quality management in construction projects in Nigeria.

The study's findings contributed to more effective quality management studies by highlighting critical barriers to the adoption of emerging technologies in construction quality management. An understanding of these barriers could aid construction practitioners, organisations, government, and policymakers in developing strategies to minimise them and promote the adoption of emerging technologies for quality management in the sector. Overcoming these barriers can improve efficiency, reduce costs and delays, and enhance build quality, thereby boosting investor confidence and supporting sustainable infrastructure. It can also drive job creation, strengthen local skills, attract foreign investment, and ultimately promote industry growth and economic development in Nigeria and other developing countries. While centred on the Nigerian context, the study's insights hold broader applicability and may guide practices in other countries with comparable socio-economic and cultural settings.

2. Literature Review

2.1. Theoretical Framework

This section explains the theoretical foundations that encourage the adoption of emerging technologies for quality management in construction. The theoretical framework offers a broad representation of the associations between elements within a particular subject. To deepen understanding of how emerging technologies for quality management in construction are adopted, the study draws on established theories. Specifically, the technology acceptance model seems to be appropriate.

2.1.1. Technology Acceptance Model

The technology acceptance model (TAM) is a widely used theory for exploring user acceptance behaviour, rooted in social psychology and drawing particularly on reasoned action theory (Ma & Liu, 2004). This theory explains how technology users come to accept and utilise technology, as shown in Figure 1 (Ma & Liu, 2004; Davis, 1989). TAM can be used to analyse the perceived usefulness and perceived ease of use of emerging technologies in construction quality management before their adoption by organisations or individuals (Davis, 1989). In the context of quality management in construction, emerging technologies such as quality management software, BIM, Blockchain, and Computer Vision often face resistance due to challenges in these areas (Tam *et al.,* 2024; Saka & Chan, 2019). For example, construction firms or workers may perceive these technologies as unnecessary or complex to use, resulting in low adoption rates. Factors such as security concerns, high costs of software and hardware, the absence of standardised guidelines and practices, and the lack of market data for technology incorporation, or low levels of knowledge and training, further compound this resistance, making it more difficult for the construction sector to take full benefit of emerging technologies.

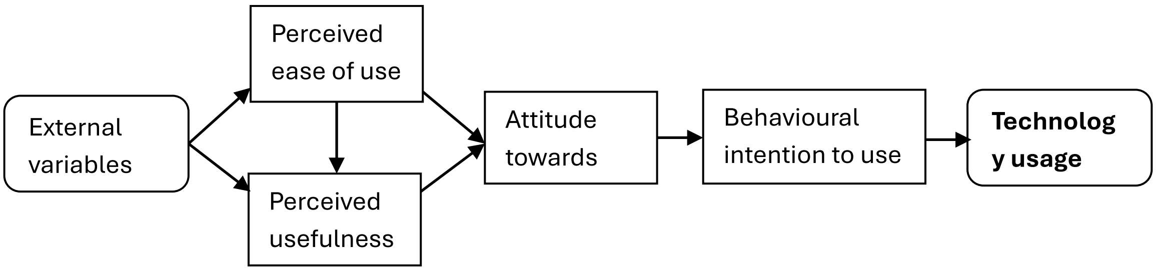

Figure 1: Technology acceptance model (Source: Ma & Liu, 2004)

Implications of the technology acceptance model for surmounting barriers to the adoption of emerging technologies in construction quality management are significant. Construction firms can develop approaches that encourage the adoption of emerging technology by tackling both perceived ease of use and usefulness. This may include better training and education programmes to demonstrate the advantages of emerging technologies for enhancing quality control, or simplifying the user interface to make digital tools more intuitive and user-friendly for construction practitioners. TAM highlights the role of organisational culture and leadership in promoting a positive attitude towards technological change (Ma & Liu, 2004; Davis, 1989). Thus, construction organisations can mitigate barriers to the adoption of emerging technologies and improve project management quality by clearly communicating long-term benefits and promoting innovation.

2.2. Barriers to Adoption of Emerging Technologies

Despite the significant advantages that emerging technologies offer for enhancing quality management in construction, their adoption remains constrained by various challenges. Recognising these obstacles is essential for practitioners, organisations, policymakers, and government bodies seeking to develop effective strategies for addressing them. Existing literature identifies a broad set of barriers, including resistance to change, data security concerns, high costs of software and hardware, a lack of standardised guidelines, limited financial resources, inadequate market information, and low levels of technical expertise, among others (Kamaruddeen *et al.*, 2022; Perera *et al.*, 2023; Maqsoom *et al.*, 2023; Chen *et al.*, 2023; Opoku *et al.*, 2023; Tam *et al.*, 2024). Although these findings highlight the complex and interconnected nature of adoption barriers, they are drawn mainly from studies in developed countries, where technological environments and support infrastructures are far more advanced.

In contrast, research emerging from African contexts, and Nigeria in particular, remains sparse, even though the benefits of digitalisation have not been evenly realised across the continent (Badaru & Mphahlele, 2023). This disparity indicates that barriers in developing countries may vary not only in scale but also in character. For instance, while cost and security concerns commonly feature in studies from developed countries, issues such as weak institutional frameworks, inadequate infrastructure, and low levels of awareness may exert a more significant influence in the Nigerian context (Azoro *et al.*, 2021; Iroha *et al.*, 2024; Oke *et al.*, 2025). Furthermore, the construction industry worldwide has been notably slow in adopting contemporary management practices (Parsamehr *et al.,* 2023). However, in Nigeria, this slow uptake is further exacerbated by limited investment in digital capabilities and a highly fragmented industry structure (Idowu *et al.*, 2023; Ibim & Dimkpa, 2025). Taken together, this highlights a notable gap in existing knowledge: although global studies discuss adoption barriers in broad terms, the specific contextual realities shaping these challenges in Nigeria remain insufficiently examined, underscoring the need for targeted research.

3. Research Methodology

The study used a quantitative research approach to determine the barriers to the adoption of emerging technologies for quality management in construction projects in Nigeria. This research approach elicits numerical data for analysis, ranking, or grouping (Creswell, 2014) and allows broad population insights within a short time (Daniel, 2016). Quantitative research relies on statistical analysis to draw conclusions and make predictions (Yilmaz, 2013), making it well-suited to this study's broad sampling approach. A literature review was conducted to identify barriers to the adoption of emerging technologies for quality management in construction. Relevant studies were located through searches in Scopus, Google Scholar, and Web of Science using keywords such as "construction," "quality management," "emerging technologies," and "barriers." Additional studies were identified through manual searches and citation tracking. Publications were included if they discussed factors that hindered the adoption or implementation of emerging technologies in construction or related sectors. Barrier-related information was manually extracted from each study. The resulting list of barriers was then used to develop the questionnaire to achieve the research objectives.

The questionnaire was utilised to gather data from survey participants regarding barriers to the adoption of emerging technologies for quality management in construction. The study used purposive sampling to select survey respondents. Purposive sampling is a non-probability approach that identifies participants based on characteristics relevant to the study objectives. The survey targeted key construction professionals, including builders, architects, electrical engineers, structural engineers, quantity surveyors, and mechanical engineers. A total of 209 respondents were selected to ensure representation across consulting, client, and contracting firms operating in construction projects in Nigeria. This approach ensured that the survey captured perspectives from professionals actively involved in the construction industry. The study considered Nigeria because the construction industry of Nigeria faces enormous challenges, including poor management, project delays, and poor quality control, among others, which may be a reason for the slow adoption of sustainable construction (Ogunmakinde *et al.*, 2019). These survey participants were selected due to their construction experience. A total of two hundred and nine (209) questionnaires were distributed to survey participants. After scrutinising the collected questionnaires, only 127 were useful, representing a 60.8% response rate. The respondents completed the questionnaire by providing feedback on barriers to the adoption of emerging technologies for quality management in construction, using a 5-point Likert scale. The scale ranged from 1 (not critical) to 5 (very critical), with 2 representing slightly critical, 3 representing moderately critical, and 4 representing critical. Data collection of this research commenced in May 2024 and was completed in July 2024. The statistical package for the social sciences analysed respondents' data using Cronbach's alpha, frequency distributions, percentages, mean scores, normalised mean analysis, and exploratory factor analysis. A reliability score of 0.904 exceeded the minimum threshold of 0.70 (Taherdoost, 2016), indicating strong internal consistency for the scale.

To identify the critical barriers to the adoption of emerging technologies in construction quality management, Normalised Mean Analysis (NMA) was employed. In this approach, the lowest mean score is standardised to 0 and the highest to 1, with all intermediate values proportionally transformed into decimal scores within this range, as illustrated in Equation 1 (Eq.1) (Munianday *et al.*, 2022; Xu *et al.*, 2010). Factors attaining a normalised mean value of 0.50 or above were classified as critical (Ayalp & Arslan, 2025).

$$\text{Normalised Mean Value} = \frac{\text{Mean} - \text{Minimum mean value}}{\text{Maximum mean value} - \text{Minimum mean value}} \ldots \text{Eq. (1)}$$

Exploratory Factor Analysis (EFA) was conducted to identify and cluster the critical barriers according to their underlying relationships. EFA enables the discovery of latent patterns in the dataset by examining inter-variable correlations without relying on predefined assumptions (Yong & Pearce, 2013). To assess the suitability of the data for factor analysis, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity were applied. The KMO statistic assesses dataset adequacy by comparing the magnitude of observed correlations with those from partial correlations (Field, 2013), with values above 0.50 generally deemed acceptable for EFA (Norusis, 2008). Bartlett's test assesses whether the correlation matrix significantly diverges from an identity matrix, with high sphericity and low p-values confirming appropriateness for factor analysis (Pallant, 2020). Following confirmation of suitability, an oblique rotation (Oblimin with Kaiser Normalization) was applied because the factors were expected to be correlated, reflecting the interrelated nature of the barriers (Rajalahti & Kvalheim, 2011). This rotation method provides a more realistic representation of the relationships among constructs, thereby enhancing the interpretability of the factor structure (Osborne, 2015). Factors with eigenvalues greater than one were retained, while only those explaining a cumulative variance above 60% were considered valid to ensure construct reliability. Furthermore, factor loadings exceeding 0.50 were maintained, as they demonstrate substantial contributions to the constructs and facilitate meaningful interpretation (Osborne, 2015).

4. Findings and Discussion

4.1. Demographic Characteristics of Respondents

From the study, the majority of respondents involved in the survey are in the 31-40-year age bracket, representing 40.93% (52). This is followed by the age bracket 41-50 years, representing 37.8% (48); 21-30 years, representing 15.7% (20); and 51 years and above, representing 5.5% (7). This shows that the survey participants are mature enough to be involved in the research. Based on the respondents' professional background, builders are 54 (42.5%), followed by architects with 28 (22%), quantity surveyors with 20 (15.7%), electrical engineers with 12 (9.4%), structural engineers with 9 (7.1%), and mechanical engineers with 4 (3.1%). For the academic qualification of the respondents, 46.5% of the study population were bachelor's degree holders, followed by postgraduate diploma holders with 30.7%, master's degree holders with 13.4%, higher national diploma holders with 5.5%, and doctorate holders with 3.9%. For work experience, 11-15 years and 16-20 years have the same number of participants with 40 (31.5%), 21 years and above have 27 (21.3%), 6-10 years have 17 (13.4%), and 1-5 years experience have 3 (2.4%). These results confirmed the respondent's eligibility to be involved in the research. Furthermore, the consulting, contracting, and client firms have 62 (48.8%), 62 (48.8%), and 3 (2.4%), respectively.

4.2. Results of Normalised Mean Analysis

Table 1 presents the results of the NMA. Nine (9) barriers have normalised mean values (NMV) greater than 0.50, indicating their criticality as barriers to emerging technologies in construction quality management. As a result, nine (9) barriers can be considered critical barriers to emerging technologies in construction quality management, namely; Regulatory and legal challenges (TB2), Uncertain return on investment (ROI) (TB5), Integration Issues (TB3), Complexity (TB6), Resistance to change (TB4), Cost (high costs of software and hardware) (TB1), Technology availability (TB11), Limited industry collaboration and standards (TB15), and Risk of technology obsolescence (TB9).

4.3. Results of Exploratory Factor Analysis

The adequacy of the sample for exploratory factor analysis (EFA) was established using the ratio of sample size to the number of variables, yielding a ratio of 14.1 for the critical barriers, which exceeds the recommended minimum of 5.0. This confirms that the sample size was sufficient for EFA. Further validation was provided by the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy, which recorded a value of 0.708, above the accepted threshold of 0.60, alongside Bartlett's test of sphericity ($\chi^2 = 623.846$, $p < 0.000$), indicating that the correlation matrix was significant and not an identity matrix (see Table 2). Together, these results demonstrate the dataset's

Table 1: Results of NMA on barriers to emerging technologies in construction quality management

Code	Barriers	Mean	Standard Deviation	NMV
TB1	Cost (high costs of software and hardware)	4.13	0.845	1.00*
TB2	Regulatory and legal challenges	3.69	0.842	0.56*
TB3	Integration Issues	3.74	0.819	0.61*
TB4	Resistance to change	3.98	1.035	0.85*
TB5	Uncertain return on investment (ROI)	3.79	1.094	0.66*
TB6	Complexity	3.67	1.016	0.54*
TB7	Lack of awareness (low level of knowledge)	3.33	1.099	0.19
TB8	Data security concerns	3.35	1.217	0.21
TB9	Risk of technology obsolescence	3.91	0.979	0.78*
TB10	Industry fragmentation	3.46	1.010	0.32
TB11	Technology availability	3.78	0.916	0.65*
TB12	Dependency on technology providers	3.16	1.130	0.02
TB13	Limited resources	3.14	1.283	0.00
TB14	Skills gap	3.35	1.257	0.21
TB15	Limited industry collaboration and standards	3.67	1.106	0.54*
TB16	Overreliance on technology	3.39	0.909	0.25

Note: NMV = Normalised Mean Value
* = Critical barriers

Table 2: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.708
Bartlett's Test of Sphericity	Approx. Chi-Square	623.846
	Df	36
	Sig.	0.000

suitability for factor analysis. The Scree plot (Figure 1) suggested the extraction of three components, guided by the 'elbow' point on the curve. The first component explained more variance than the combined variance of the remaining components, while the second and third components were distinctly separated, underlining their individual contributions.

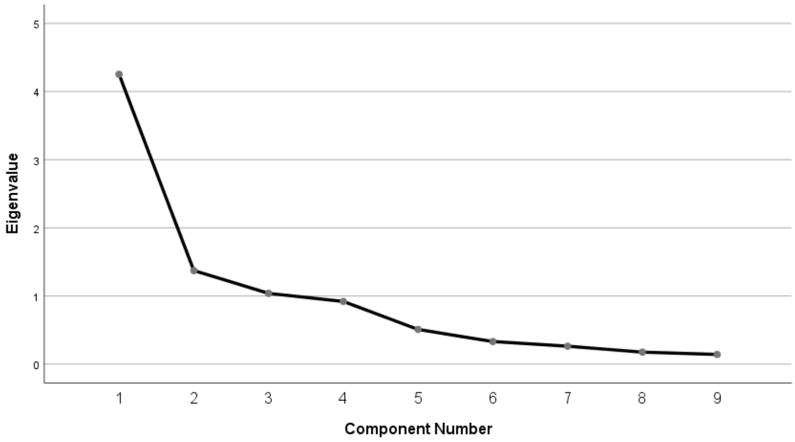

Figure 1: Scree plot

Regarding factor loadings, values between 0.30 and 0.40 are generally considered the minimum threshold for practical significance (Ho, 2013). In this study, a cut-off of 0.30 was applied, and only loadings above this value were retained. Although a minimum loading threshold of 0.30 was adopted per established guidelines, the actual loadings observed in this study were substantially higher. Most items loaded strongly onto their respective components, with observed loadings generally exceeding 0.50. This indicates robust relationships between the variables and the extracted components, further supporting the reliability of the factor structure. Communalities ranged between 0.54 and 0.87, which are acceptable and indicate low to high levels of shared variance, thereby supporting the reliability of the extracted constructs (Costello and Osborne, 2005). As presented in Table 3, the first three critical barriers to emerging technologies in construction quality management recorded eigenvalues greater than 1 (4.253, 1.373, and 1.038), meeting the criterion for factor retention. Collectively, these three components explained 74.04% of the total variance, surpassing the recommended 60% threshold for construct adequacy (Ghosh and Jimtanapakamont,

Table 3: The total variance explained by the critical barriers to emerging technologies in construction quality management

Critical Barriers	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings[a]
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
TB1	4.253	47.254	47.254	4.253	47.254	47.254	2.726
TB2	1.373	15.252	62.505	1.373	15.252	62.505	2.540
TB3	1.038	11.532	74.038	1.038	11.532	74.038	3.160
TB4	.919	10.214	84.252				
TB5	.508	5.649	89.901				
TB6	.331	3.674	93.574				
TB9	.262	2.915	96.489				
TB11	.175	1.947	98.436				
TB15	.141	1.564	100.000				

Extraction Method: Principal Component Analysis.
[a]When components are correlated, sums of squared loadings cannot be added to obtain a total variance.

2004). The rotated factor matrix is presented in Table 4.

Table 4: The factor matrix after rotation

Code	Critical barriers to emerging technologies in construction quality management	Extracted Communalities	Component		
			1	2	3
Component 1: Institutional and regulatory barrier					
TB2	Regulatory and legal challenges	0.767	0.765		
TB5	Uncertain return on investment (ROI)	0.744	0.741		
TB3	Integration Issues	0.539	0.708		
Component 2: Organisational barrier					
TB6	Complexity	0.794		0.845	
TB4	Resistance to change	0.732		0.747	
TB1	Cost (high costs of software and hardware)	0.579		0.636	
Component 3: Technology and industry collaboration barrier					
TB11	Technology availability	0.836			0.912
TB15	Limited industry collaboration and standards	0.872			0.794
TB9	Risk of technology obsolescence	0.801			0.723

Extraction Method: Principal Component Analysis
Rotation Method: Oblimin with Kaiser Normalization
Rotation converged in 14 iterations

4.4. Discussion on Key Findings

This part of the paper discusses the three underlying constructs (i.e. institutional and regulatory, organisational, and technology and industry collaboration barriers) hindering the adoption of emerging technologies in construction quality management and their critical barriers. To enhance clarity, the relationship between individual items and the factor labels was examined based on both statistical loadings and conceptual alignment. Items were assigned to factors not solely based on loading strength, but because their underlying meanings reflected shared thematic constructs identified in prior literature. For example, the item "integration issues" was grouped under Institutional/Regulatory barriers because the integration challenges reported by respondents largely arise from external systemic constraints, such as the absence of unified digital standards, lack of regulatory frameworks, and poor inter-organisational coordination, rather than from technical limitations within firms. Similarly, items loading on the Organisational and Technical factors reflect internal capabilities, resources, and operational practices within construction firms. This combined statistical–conceptual approach ensures that factor labels accurately represent the nature of the grouped barriers.

4.4.1. Institutional and Regulatory Barriers

Institutional and regulatory barriers emerged as the strongest underlying construct, explaining 47.25% of the total variance (see Table 3). This factor comprises three key items: (1) regulatory and legal challenges, (2) uncertain return on investment, and (3) integration issues. These findings align with evidence from other developing contexts such as Ghana and Malaysia (Pittri *et al.*, 2025; Thirumal *et al.*, 2024; Yap *et al.*, 2022). Collectively, these items indicate that macro-level institutional constraints, such as weak regulatory frameworks, unclear digital requirements, and fragmented integration standards, significantly shape firms' perceptions of risk and value when considering emerging technologies for quality management. Uncertain return on investment (ROI) further discourages organisations from committing resources to technologies whose long-term benefits remain ambiguous (Hassan *et al.*, 2024; Struckell *et al.*, 2022). Integration challenges compound these issues, particularly in environments where legacy systems, siloed vendor solutions, and the absence of common data standards inhibit seamless technology adoption (Whyte *et al.*, 2022; Basiru *et al.*, 2022).

Interpreted through the TAM, these barriers predominantly affect perceived usefulness and perceived ease of use. First, regulatory uncertainty and unpredictable ROI weaken perceived usefulness by reducing organisational confidence that technology adoption will lead to tangible performance improvements. Second, integration issues increase perceived complexity, thereby lowering perceived ease of use. Together, these effects diminish behavioural intention to adopt emerging technologies, consistent with TAM's premise that perceived usefulness and perceived ease of use are primary determinants of adoption decisions.

These findings underscore the need for stronger institutional support mechanisms to enhance technology uptake in Nigeria's construction sector. Policymakers and regulators should establish clear digital standards, procurement guidelines, and liability frameworks to reduce legal ambiguity and foster greater interoperability across systems. Incentives or supportive financing schemes may also help mitigate firms' concerns about ROI. Strengthening these institutional conditions would enhance both perceived usefulness and perceived ease of use, ultimately improving industry-wide adoption intentions and contributing to more effective digital integration in quality management practices.

4.4.2. *Organisational Barriers*

Organisational barriers emerged as the second underlying construct, explaining an additional 15.25% of the variance, bringing the cumulative explained variance to 62.51% (see **Table 3**). This factor captures internal organisational constraints that hinder the adoption of emerging technologies, including technological complexity, workforce resistance to change, and high implementation costs. Similar findings have been reported in India and Vietnam (Tam *et al.*, 2024; Ramanna *et al.*, 2024; Thirumal *et al.,* 2024; Luo *et al.*, 2022). Complex technologies typically require specialised skills, extensive training, and significant workflow adjustments, demands that can overwhelm firms with limited technical capacity. Resistance to change also plays a substantial role, as employees may view new digital systems as disruptive or threatening to their established work practices. Furthermore, the high costs of acquiring, integrating, and maintaining advanced digital tools pose significant financial constraints, particularly for firms operating in developing economies, where profit margins and investment capital are limited (Ajiga *et al.*, 2024).

When interpreted through TAM, these organisational barriers primarily affect perceived ease of use and perceived usefulness. Technological complexity and employee resistance reduce perceived ease of use by increasing expectations of difficulty, training burden, and workflow disruption. High costs and uncertain short-term benefits weaken perceived usefulness, as firms question whether the expected performance improvements justify the financial and organisational investment required. Together, these effects diminish behavioural intention, thereby slowing or preventing actual adoption.

To address these organisational barriers, construction firms should implement structured change-management strategies, including early employee involvement, targeted training programmes, and clear communication of expected benefits. Staged or incremental investment approaches can help reduce financial pressure and allow organisations to build capacity gradually. Generating early, visible benefits, such as reductions in rework, faster inspections, or improved documentation quality, can strengthen perceived usefulness and perceived ease of use among employees, reinforcing TAM's causal pathways and accelerating adoption. Policymakers and industry associations may also play a supporting role by offering subsidised training or sharing best practices to enhance organisational readiness.

4.4.3. *Technology and Industry Collaboration Barriers*

Technology and industry collaboration barriers emerged as the third underlying construct, contributing an additional 11.53% of the variance, and raising the total cumulative variance explained by the three components to 74.04% (see **Table 3**). This factor comprises issues related to technology availability, lack of industry-wide collaboration and standards, and fears of technological obsolescence. Similar patterns have been identified in previous studies (Pittri *et al.*, 2025; Tam *et al.*, 2024; Luo *et al.*, 2022; Yap *et al.*, 2022). Limited access to appropriate digital tools restricts firms' ability to explore and implement innovations, particularly in environments with weak digital infrastructure (Pittri *et al.*, 2025). The absence of shared standards and collaborative frameworks intensifies fragmentation, leading to compatibility issues and slow diffusion across the sector (Kelvin & Aliu, 2025; Soltani *et al.*, 2025). Additionally, the rapid pace of technological development heightens fears of obsolescence, discouraging firms from investing in solutions that may quickly lose relevance (Păvăloaia & Necula, 2023; Cascio & Montealegre, 2016). These barriers demonstrate that adoption is influenced not only by internal organisational readiness but also by the broader technological ecosystem and the level of collaboration within the industry.

Using the TAM framework, these barriers primarily impact perceived usefulness and behavioural intention. Concerns about obsolescence and interoperability diminish perceived usefulness by reducing confidence that the technology will deliver sustained value over time. Limited industry collaboration and the absence of standardised practices undermine behavioural intention by introducing uncertainty about future compatibility, vendor support, and long-term viability. Organisations become hesitant to adopt technologies that lack clear industry endorsement or stable integration pathways.

These findings highlight the importance of strengthened industry collaboration, coordinated standard-setting, and reliable vendor support systems. Industry associations, regulatory agencies, and technology providers should work together to establish interoperability standards, promote joint testing and pilot initiatives, and ensure long-term support for key technologies. Such collaborative efforts can improve the reliability and compatibility of emerging technologies, thereby increasing perceived usefulness and reducing adoption hesitancy. By enhancing the industry-wide environment, stakeholders can reinforce TAM's predictive mechanisms and accelerate the diffusion of technology in construction quality management.

Taken together, the three underlying constructs, institutional and regulatory barriers, organisational barriers, and technology and industry collaboration barriers, demonstrate that a combination of macro-level institutional conditions, firm-level readiness, and sector-wide technological dynamics shapes the adoption of emerging technologies in construction quality management. When interpreted through the Technology Acceptance Model, these barriers collectively weaken perceived usefulness**,** perceived ease of use, and ultimately behavioural intention, illustrating that the challenges to digital adoption are interconnected rather than isolated. Strengthening regulatory clarity, enhancing organisational capacity, and improving technological interoperability across the industry are therefore essential strategies for improving perceptions of value and usability. Addressing these multi-level constraints can create a more enabling environment for technology uptake, reinforcing TAM's relevance in explaining adoption behaviour within the construction sector and supporting more effective digital transformation in quality management practices.

5. Conclusion and Further Research

This study provides empirical evidence on the barriers hindering the adoption of emerging technologies for construction quality management in Nigeria. In this context, integration remains significantly slower than in the Global North. Using data from 127 practitioners and applying exploratory factor analysis, the study establishes a three-factor structure: institutional and regulatory barriers, organisational barriers, and technology and industry collaboration barriers, that collectively explain the significant constraints to adoption. This factor structure represents the study's core contribution, offering a systematic framework for understanding how fragmented regulations, organisational readiness gaps, and weak technological ecosystems jointly impede the diffusion of technology in developing-country construction sectors.

The findings add new insights to the literature on the Global South by showing how regulatory uncertainty, low industry collaboration, and technology obsolescence risks are especially pronounced in Nigeria's construction environment, where digital infrastructure is weaker, and investment capacity is limited. These contextual nuances help explain why adoption patterns diverge from those typically reported in high-income countries.

Based on the three-factor structure, the study offers three practical recommendations. First, policymakers should strengthen and harmonise regulatory and standards frameworks to reduce uncertainty and improve interoperability across firms. Second, construction organisations should invest in structured change management, training, and phased implementation strategies to address internal resistance and complexity. Third, industry associations and technology vendors should collaborate to build shared digital platforms, standards, and support systems, lowering costs and mitigating fears of obsolescence. These actions collectively target the key barriers identified by the model.

The study is not without limitations. It focuses on Nigerian practitioners and relies solely on quantitative survey data, which may not fully capture deeper institutional or cultural dynamics. Additionally, TAM was used only as an interpretive lens rather than being empirically operationalised. Future research should integrate qualitative methods, undertake comparative case studies across regions, and directly measure TAM constructs such as perceived usefulness and behavioural intention to provide stronger empirical validation of adoption pathways in construction quality management.

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