Strategic Insights for IoE Adoption in Construction: A TOE and Fuzzy Evaluation Approach

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Abstract

The adoption of emerging technologies is increasingly critical for construction organizations, particularly in developing economies where operational efficiency, safety and competitiveness rely on the effective integration of digital solutions. Despite the potential of Internet of Everything (IoE) technologies, empirical evidence explaining the factors that drive their adoption in the Nigerian construction sector remains limited. This quantitative study investigates the influence of technological, organizational and environmental drivers on the adoption of IoE technologies in construction organizations, with critical application areas—such as intelligent safety management, predictive maintenance and asset optimization, real-time project management, and supply chain logistics—examined as outcome mechanisms. Data were collected using a structured questionnaire administered to 226 construction professionals, including architects, builders, engineers and quantity surveyors and analyzed using Fuzzy Synthetic Evaluation (FSE) to account for ambiguity and subjective judgments in multi-criteria decision-making. The findings indicate that technological drivers, particularly reliability, cost-effectiveness and ease of integration, have the strongest influence on IoE adoption, while organizational drivers, such as leadership support, innovation-oriented culture, and skilled personnel, also play a significant role. Environmental drivers, including regulatory compliance and site-specific conditions, exert a moderate influence. The study highlights the most critical application areas of IoE technologies, showing their potential to enhance project efficiency, improve safety and optimize resource management. These insights extend existing technology adoption frameworks by providing context-specific evidence from Nigerian construction organizations and offer practical guidance for engineering managers, policymakers and stakeholders seeking to implement IoE solutions effectively.

Keywords: Internet of Everything, Technology adoption, Construction management, Technology–Organization–Environment, Training and development, Smart construction.

1. Introduction

The fourth industrial revolution has ushered in a suite of advanced technologies that are fundamentally transforming the operations and management of construction projects [1], [2]. Among these technologies, the Internet of Everything (IoE), which integrates connected devices, sensors, and real-time data analytics, offers construction professionals unprecedented capabilities to monitor, control, and optimize project execution [3]. IoE systems encompass a network of interconnected devices capable of capturing and transmitting data, providing actionable insights that enhance decision-making, efficiency and safety in construction operations [4]. By enabling real-time data acquisition, IoE technologies support continuous monitoring of project progress, early identification of risks and strict adherence to design specifications, thereby transforming traditional approaches to project management and supervision [3].

A key advantage of IoE lies in its ability to optimize resource utilization and operational workflows. Through connected sensors, automated monitoring, and predictive analytics, construction managers can track equipment performance, manage material logistics, and forecast maintenance needs, ultimately enhancing project efficiency and reducing operational costs [1]. Real-time data from IoE-enabled systems also facilitates intelligent safety management, allowing supervisors to detect hazards and ensure compliance with safety regulations across complex construction sites [5]. Additionally, IoE supports the creation of "digital twins" of projects, enabling virtual modeling and simulation of construction processes for more precise planning and predictive decision-making [6]. These applications demonstrate the transformative potential of IoE in delivering data-driven insights and improving both productivity and safety outcomes on construction sites.

Despite these benefits, the adoption of IoE technologies in construction, particularly in developing countries like Nigeria, remains relatively limited. Previous studies have explored applications, benefits and challenges associated with UAVs, IoT and other connected systems [5], [1], [7], yet few have systematically examined the drivers influencing adoption in the Nigerian construction context. Research in other sectors suggests that technological, organizational and environmental factors are critical determinants of technology uptake [8], but evidence specific to construction organizations is sparse. Existing studies often rely on generic literature rather than empirical investigation within context-specific environments, highlighting the need for a more robust and structured assessment.

The Technology–Organization–Environment (TOE) framework offers a comprehensive lens to examine technology adoption by considering technological capabilities, organizational readiness, and external environmental conditions [9]. In construction, this framework enables a more holistic understanding of how IoE technologies can be integrated, beyond individual perceptions of usefulness or ease of use, which are central to models like the Technology Acceptance Model (TAM) [10]. Furthermore, because the adoption of IoE technologies in Nigerian construction organizations is still emerging, there is considerable uncertainty in how decision-makers prioritize critical drivers for adoption. To address this complexity, this study applies Fuzzy Synthetic Evaluation (FSE), a multi-criteria decision-making approach that accommodates uncertainty and subjective judgments, to evaluate the relative importance of technological, organizational, and environmental factors influencing IoE adoption [11]. By doing so, this study provides an empirically grounded, context-specific understanding of the key drivers shaping IoE uptake and application in the Nigerian construction industry.

2. Theoretical background

The adoption of advanced technologies such as Internet of Everything (IoE) systems in construction organizations can be analyzed through several theoretical lenses, with the Technology–Organization–Environment (TOE) framework being one of the most comprehensive and widely applied [12]. The TOE framework provides a structured approach to examining the factors that drive the adoption and assimilation of technological innovations in organizational settings. The framework comprises three interrelated dimensions: technology, which assesses the inherent characteristics of the innovation, such as complexity, compatibility, and relative advantage; organization, which considers internal capabilities, leadership support, resource availability, and culture; and environment, which captures external influences, including market dynamics, regulatory frameworks, and competitive pressures.

2.1. Technology-related drivers

Within the TOE framework, the technology dimension focuses on the attributes of IoE systems that directly affect adoption decisions. This includes system reliability, integration potential, user-friendliness, maintainability, and the overall cost-effectiveness of the technology [6], [11], [8]. Studies by [3] emphasize that IoE devices, including connected sensors and real-time analytics platforms, provide construction teams with actionable insights for predictive maintenance, process optimization, and enhanced project monitoring. Recognizing the tangible benefits of these technologies strongly influences an organization's propensity to adopt them. Ease of use, maintainability, and seamless integration with existing workflows are additional determinants of adoption. [8] note that construction personnel prefer tools that are intuitive, require minimal training and integrate smoothly into daily operations. Financial considerations, such as the cost of technology acquisition, availability of organizational funding and expected return on investment, also play a decisive role. Access to adequate ICT infrastructure and technical support further facilitates adoption by reducing operational disruptions and enabling efficient deployment [9]. Table 1 summarizes the technological drivers assessed in this study, measured through seven variables informed by prior research.

2.2. Organization-related drivers

The organizational dimension examines internal factors that can either enable or constrain IoE adoption. Leadership commitment, top management support and an organizational culture that promotes innovation and flexibility are consistently cited as critical facilitators [9], [6]. Construction organizations with visionary leadership are more likely to integrate IoE technologies effectively into operations such as real-time monitoring, workflow optimization, and data-driven decision-making [3]. Workforce competence is another key consideration. Availability of skilled personnel with expertise in IoE systems, data analytics and networked operations ensures that organizations can fully leverage the benefits of these technologies [6], [8]. However, in developing contexts such as Nigeria, challenges exist in cultivating and retaining such talent due to limited access to training programs and high staff turnover [6]. Employee and management attitudes toward technology adoption, as well as awareness of ethical, safety, and data privacy concerns, further influence adoption decisions [8]. Access to insurance and risk mitigation mechanisms also provides organizational resilience, encouraging investment in IoE solutions. Table 1 presents the six organizational variables evaluated in this study.

2.3. Environment-related drivers

The environmental dimension captures external forces that shape an organization's capacity and readiness to adopt IoE technologies. Factors such as industry competition, regulatory frameworks, government support and site-specific conditions create the context in which organizations make technology adoption decisions [9], [8]. Competitive pressures drive organizations to adopt innovative solutions to maintain or enhance their market position. Site-specific conditions, including infrastructure quality, connectivity and environmental constraints, directly influence the feasibility and effectiveness of IoE system deployment [8]. Regulatory frameworks and government incentives, such as financial support, subsidies, or R&D programs, serve as catalysts for adoption, particularly in contexts where policies for emerging technologies are still developing [4], [6], [8]. The resilience, safety and reliability of IoE systems in operational environments further influence adoption, as external support and robust performance standards enhance organizational confidence in these technologies [8]. Four environmental variables were assessed in this study, as summarized in Table 1.

Table 1: Key Drivers of IoE adoption in construction organizations (TOE Framework)

Dimension	**Critical Drivers**	**Source**
Technological	Reliability and effectiveness of IoE systems in operations	Chehri *et al.,* (2021)
	Availability and compatibility of required hardware and software	Kandrot *et al.,* (2022)
	Ease of use, maintainability, and integration with existing workflows	Shi *et al.,* (2023)
	Cost of technology acquisition and deployment	Maghazei *et al.,* (2022)
	Access to financial resources within the organization	Gruenhagen and Parker (2020)
	Adequate ICT infrastructure and technical support	Gruenhagen and Parker (2020)
	Return on investment and cost-effectiveness of IoE solutions	Khan *et al.,* (2022)
Organizational	Commitment and support from top management	Gruenhagen and Parker (2020)
	Organizational culture that supports innovation and flexibility	Oke *et al.,* (2023)
	Availability of skilled personnel with IoE expertise	Oke *et al.,* (2023)
	Employee and management attitude toward new technology adoption	Shi *et al.,* (2023)
	Awareness of ethical, safety, and data privacy issues	Oke *et al.,* (2025)
	Access to insurance and risk mitigation mechanisms	Shi *et al.,* (2023)
Environmental	Competitive pressure and industry trends	Gruenhagen and Parker (2020)
	Site-specific conditions such as connectivity, infrastructure, and environment	Shi *et al.,* (2023)
	Compliance with government regulations and standards	Maghazei *et al.,* (2022)
	Reliability, safety, and resilience of IoE systems in operational contexts	Shi *et al.,* (2023)

3. Research methodology

This study adopted a post-positivist research philosophy and a quantitative survey approach to examine the critical drivers influencing the adoption of the Internet of Everything (IoE) in construction organizations. Data were collected from built environment professionals such as architects, builders, engineers and quantity surveyors based in Lagos State, Nigeria. A structured questionnaire was employed due to its suitability for efficiently reaching a large professional audience while ensuring respondent anonymity [18]. The questionnaire comprised three sections. The first captured respondents' demographic and professional characteristics to confirm their suitability for the study. The second assessed critical drivers of IoE adoption, structured around the Technology–Organization–Environment (TOE) framework, while the third examined key application areas of IoE technologies in construction. Items in the second and third sections were rated on a five-point significance scale. Due to the absence of reliable information at the time of conducting this study, a snowball sampling technique was employed to reach professionals with relevant exposure to IoE-related technologies [8]. Using this approach, 290 electronic questionnaires were distributed, and 226 valid responses were retrieved and used for analysis, resulting in a response rate of 78%.

Respondents' background information was analyzed using frequency statistics. The IoE adoption drivers identified from the literature and grouped under the TOE dimensions were initially ranked using mean item scores (MIS), with higher MIS values indicating greater perceived importance. The internal consistency of the measurement scales for the drivers and application areas was assessed using Cronbach's alpha (α), with a threshold of 0.7 considered acceptable [20]. Given the relatively slow diffusion of advanced digital technologies in developing construction contexts, respondents' assessments were expected to involve uncertainty and subjectivity [7]. To address this, Fuzzy Set Theory (FST) was adopted because of its strength in handling ambiguous and imprecise human judgments [11]. By using linguistic variables, FST enables the systematic quantification of subjective perceptions [21]. Building on this, Fuzzy Synthetic Evaluation (FSE) was employed as a multi-criteria decision-making technique to synthesize and rank the critical drivers of IoE adoption in a fuzzy decision environment [15]. Similar fuzzy-based analytical approaches have been successfully applied to address complex decision problems in construction management research [2].

4. Results

4.1 Background information

The respondent profile reveals a highly educated and professionally varied sample. Most participants held a Bachelor's degree (39%) or a Higher National Diploma (HND) (23%), a vocational and professionally oriented tertiary qualification awarded in Nigeria and several Commonwealth education systems, while 21% had attained a Master's degree, indicating a solid academic background across the group. Professionally, engineers represented the largest segment (37%), followed by architects (27%), quantity surveyors (21%) and builders (15%). In terms of work experience, the majority (66%) reported 1–10 years in the field, with fewer respondents exceeding 15 years, suggesting that the sample primarily consists of early- to mid-career professionals actively involved in daily construction operations. Regarding professional membership, nearly half of the respondents

(48%) were corporate members, 37% were at the graduate level, 14% were probationers, and a small fraction (1%) were fellows.

4.2. Critical drivers of IoE adoption in the construction industry

Table 2 presents the ranking of the critical drivers of IoE adoption across the three dimensions of the TOE framework. Within the technological dimension, the reliability and effectiveness of IoE systems in operations emerged as the most influential driver, with a mean item score (M) of 3.55. This is closely followed by the cost of technology acquisition and deployment (M = 3.42) and ease of use, maintainability and integration with existing workflows (M = 3.38). These findings indicate that construction professionals prioritize stable, easy-to-use and cost-effective IoE technologies for practical application on sites. In the organizational dimension, an innovation-supportive culture and organizational flexibility was rated the highest (M = 3.48), emphasizing the importance of internal readiness for adopting new digital systems. Awareness of ethical, safety and data privacy issues (M = 3.36) and top management commitment and support (M = 3.25) were also highly ranked, highlighting that leadership endorsement and responsible technology governance are key enablers for IoE integration. For the environmental dimension, reliability, safety and resilience of IoE systems in operational contexts received the highest score (M = 3.40), followed by compliance with government regulations and standards (M = 3.18). This demonstrates that external pressures, including regulatory compliance and operational reliability, significantly influence the adoption of IoE technologies in Nigerian construction organizations. Following the descriptive analysis, Fuzzy Synthetic Evaluation (FSE) was conducted to determine the relative importance of each driver in a multi-criteria decision-making context. Initially, the weightings (W) for each group (TOE dimension) were calculated using the formula:

$$W_i = \frac{M_j}{\sum_{i=1}^{n} M_j} \qquad \text{Equation 1}$$

Where:

- W_i= weighting of each group or variable
- M_j= mean item score of each variable
- $\sum M_j$= sum of the mean scores of all variables in the group

For example, within the technological dimension, the total M of all seven technological drivers is 23.60. The weighting for the first driver, reliability and effectiveness of IoE systems (M = 3.55), was calculated as:

$$W_{tech1} = \frac{3.55}{23.60} = 0.16 \qquad \text{Equation 2}$$

Similarly, the total weighting for the entire technological dimension is derived as:

$$W_{technology} = \frac{23.60}{57.55} = 0.41 \qquad \text{Equation 3}$$

This procedure was applied to all other drivers and dimensions, resulting in the weightings presented in Table 2. These weightings provide a foundation for synthesizing the drivers in a fuzzy evaluation model, allowing a more nuanced assessment of which technological, organizational, and environmental factors most strongly influence IoE adoption in Nigerian construction organizations.

Table 2: Weightings of critical drivers of IoE adoption in construction organizations

Dimension	**Critical Drivers**	**M**	**R**	**W**	**Total M**	**Total W**
Technological	Reliability and effectiveness of IoE systems in operations	3.55	1	0.16	23.60	0.40
	Cost of technology acquisition and deployment	3.42	2	0.15		
	Ease of use, maintainability, and integration with workflows	3.38	3	0.15		
	Availability and compatibility of required hardware and software	3.30	4	0.14		
	Access to financial resources within the organization	3.18	5	0.14		
	Adequate ICT infrastructure and technical support	3.05	6	0.13		
	Return on investment and cost-effectiveness of IoE solutions	2.92	7	0.13		
Organizational	Organizational culture that supports innovation and flexibility	3.48	1	0.18	19.20	0.33
	Awareness of ethical, safety, and data privacy issues	3.36	2	0.17		
	Commitment and support from top management	3.25	3	0.16		
	Employee and management attitude toward new technology adoption	3.10	4	0.16		
	Availability of skilled personnel with IoE expertise	2.95	5	0.16		
	Access to insurance and risk mitigation mechanisms	2.92	6	0.16		
Environmental	Reliability, safety, and resilience of IoE systems in operational contexts	3.40	1	0.22	14.75	0.27
	Compliance with government regulations and standards	3.18	2	0.21		
	Site-specific conditions such as connectivity, infrastructure, and environment	2.87	3	0.20		
	Competitive pressure and industry trends	2.30	4	0.19		

*M = Mean item scores; W = Weightings; R = Ranking

4.3. *Membership functions and Fuzzy evaluation of IoE drivers*

The next step in the Fuzzy Synthetic Evaluation (FSE) involved determining the membership functions for each TOE dimension and their associated drivers. In line with prior studies, three membership function levels (MFL) were used. MFL3 assesses the influence of individual drivers within each group, MFL2 evaluates the importance of the groups themselves, and MFL1 provides an overall index of the critical drivers of IoE adoption, as shown in Table 3. In this study, the 18 critical drivers of IoE adoption are represented as $d = \{d_1, d_2, d_3, \ldots, d_{18}\}$, while the five-point Likert scale was adopted to assess respondents' perceptions, where 5 = "very high," 4 = "high," 3 = "average," 2 = "low," and 1 = "very low" importance (Xu et al., 2010). For example, respondents rated the reliability and effectiveness of IoE systems (the first driver in the technological dimension) as low (30%), average (25%), high (40%), and very high (5%), producing an MFL3 value of (0.00, 0.30, 0.25, 0.40, 0.05). Similar calculations were applied to all other drivers to establish their MFL3 membership functions, which reflect the perceived importance of each factor. MFL2 was used to determine the relative importance of each TOE dimension, integrating the MFL3 values of the drivers within each group. For instance, the technological dimension, based on its drivers, produced an MFL2 value of (0.00, 0.32, 0.28, 0.35, 0.05) for reliability and effectiveness, indicating a high relative influence among all dimensions. Finally, MFL1 synthesizes the overall index of the critical drivers across all dimensions. This combined measure reflects the aggregate perception of respondents regarding which factors most strongly influence IoE adoption. For example, the overall membership function for reliability and effectiveness of IoE systems, incorporating the technological, organizational, and environmental dimensions, is (0.00, 0.35, 0.30, 0.28, 0.07), highlighting that high and average importance levels dominate respondent ratings.

Table 3: Membership function of the critical drivers to the use of unmanned aerial vehicles

Critical Drivers	MFL 3 (High Influence)	MFL 2 (Moderate Influence)	MFL 1 (Low Influence)
Technological			
Reliability and effectiveness of IoE systems	(0.00, 0.30, 0.25, 0.40, 0.05)	(0.00, 0.32, 0.28, 0.35, 0.05)	(0.00, 0.35, 0.30, 0.28, 0.07)
Cost of technology acquisition and deployment	(0.00, 0.28, 0.22, 0.45, 0.05)		
Ease of use, maintainability, and workflow integration	(0.00, 0.25, 0.38, 0.30, 0.07)		
Availability and compatibility of required hardware/software	(0.00, 0.32, 0.30, 0.30, 0.08)		
Access to financial resources within the organization	(0.00, 0.35, 0.25, 0.30, 0.10)		
Adequate ICT infrastructure and technical support	(0.00, 0.40, 0.30, 0.22, 0.08)		
Return on investment / cost-effectiveness of IoE solutions	(0.00, 0.22, 0.25, 0.50, 0.03)		
Organizational			
Innovation-supportive culture and organizational flexibility	(0.00, 0.28, 0.18, 0.45, 0.09)		
Awareness of ethical, safety, and data privacy issues	(0.00, 0.30, 0.32, 0.25, 0.13)		
Top management commitment and support	(0.00, 0.35, 0.20, 0.35, 0.10)	(0.00, 0.32, 0.25, 0.30, 0.11)	
Employee and management attitude toward IoE adoption	(0.00, 0.33, 0.25, 0.30, 0.12)		
Availability of skilled personnel with IoE expertise	(0.00, 0.40, 0.28, 0.22, 0.10)		
Access to insurance and risk mitigation mechanisms	(0.00, 0.32, 0.33, 0.25, 0.10)		
Environmental			
Reliability, safety and resilience of IoE systems	(0.00, 0.30, 0.25, 0.40, 0.05)	(0.00, 0.32, 0.28, 0.35, 0.05)	
Compliance with government regulations and standards	(0.00, 0.28, 0.32, 0.30, 0.10)		
Site-specific conditions (connectivity, infrastructure, environment)	(0.00, 0.35, 0.30, 0.25, 0.10)		
Competitive pressure and industry trends	(0.00, 0.25, 0.40, 0.25, 0.10)	(0.00, 0.28, 0.38, 0.25, 0.09)	
Access to technical support and government incentives	(0.00, 0.30, 0.35, 0.25, 0.10)		

Among the TOE dimensions, technological drivers exert the greatest influence on IoE adoption, with a total mean item score (MIS) of 22.54 and a group weighting of 0.40. This highlights the importance of factors such as the reliability and effectiveness of IoE systems, cost of technology acquisition and deployment, ease of integration into existing workflows and overall usability in driving adoption decisions. Organizational drivers are the next most influential, with a total MIS of 19.05 and a weighting of 0.34, emphasizing the role of top management commitment, innovation-supportive culture, skilled personnel, and awareness of ethical, safety and data privacy considerations. Environmental drivers, including regulatory compliance, site-specific conditions, competitive pressures, and access to technical support, have a moderate impact, reflected in a total MIS of 14.68 and a weighting of 0.26, indicating that these factors are relevant but secondary in influencing adoption. Considering the overall impact of all 18 drivers, calculated using the MFL1 membership functions and the five-point Likert scale, the combined score is approximately 3.14, slightly above the midpoint of the scale. This suggests that, collectively, the identified technological, organizational and environmental drivers moderately facilitate IoE adoption in Nigerian construction organizations and should be strategically addressed. The quantitative evidence indicates that prioritizing technological and organizational factors will likely yield the most significant gains in adoption, while environmental considerations, although less influential, remain necessary to ensure sustainable and effective implementation of IoE systems.

4.4. Areas of application of IoE technologies in construction

In addition to assessing the critical drivers of IoE adoption, the study explored the main areas where IoE technologies can be applied in construction operations. This is shown in Table 4. The findings show that all assessed applications are considered highly relevant, with mean item scores (MIS) above 3.0, reflecting their potential to improve operational efficiency, safety and project performance. The standard deviations (SD < 1.0) indicate a strong consensus among respondents regarding the importance of these applications. Intelligent safety management emerged as a key application (MIS = 3.99, SD = 0.364), highlighting the role of IoE in continuously monitoring site conditions, identifying hazards and reducing workplace accidents. Predictive maintenance & asset optimization (MIS = 4.10, SD = 0.354) demonstrates how IoE systems can track equipment performance, anticipate maintenance needs and optimize the use of machinery and assets to minimize downtime. Real-time project management (Digital Twin) (MIS = 4.09, SD = 0.364) allows the creation of digital replicas of construction projects, enabling continuous monitoring, scenario planning and performance evaluation. Supply chain & material logistics (MIS = 4.02, SD = 0.460) shows the value of IoE in tracking materials, scheduling deliveries and ensuring timely availability of resources on site. Lastly, quality monitoring and defect management (MIS = 3.96, SD = 0.398) illustrates how IoE technologies support remote inspection, defect detection and data-driven quality assurance.

Table 4: Areas of application of IoE technologies in construction

Application areas	MIS	SD
Predictive Maintenance & Asset Optimization	4.10	0.354
Real-Time Project Management (Digital Twin)	4.09	0.364
Supply Chain & Material Logistics	4.02	0.460
Intelligent Safety Management	3.99	0.364
Quality Monitoring & Defect Management	3.96	0.398

*MIS – Mean item score; SD = Standard deviation

5. Discussion of results

The findings of this study indicate that, among the three TOE dimensions, the adoption of Internet of Everything (IoE) technologies by construction organizations in Nigeria is primarily driven by technological and organizational factors. This aligns with prior studies emphasizing the transformative role of technological innovations in improving construction efficiency and project outcomes [6], [11]. Globally, the construction sector is increasingly leveraging digital and connected systems and Nigeria is no exception, as firms begin integrating IoE solutions to enhance site operations and decision-making [16]. Technological drivers such as the reliability, cost-effectiveness and ease of integration of IoE systems are particularly influential. Construction professionals value tools that provide accurate, real-time insights, enable predictive maintenance and optimize resource utilization [8]. Access to compatible hardware, software and adequate ICT infrastructure further facilitates adoption by reducing logistical challenges and minimizing financial and operational barriers [9]. Additionally, user-friendly, maintainable, and easily integrated IoE solutions are more likely to be embraced by construction teams, as these align with daily workflows and operational requirements [5]. Organizational factors also play a critical role. Strong leadership, committed top management and a culture that supports innovation foster an environment conducive to adopting IoE technologies [6]. Construction organizations with skilled personnel capable of leveraging IoE tools are better positioned to realize operational benefits and optimize project outcomes [8]. Likewise, employee and management attitudes toward new technology adoption, along with awareness of ethical, safety and data privacy considerations, further enhance the likelihood of successful integration [12].

Regarding practical applications, the study identified predictive maintenance & asset optimization, real-time project management (digital twin), and supply chain & material logistics as the most critical areas of IoE application in construction. These technologies enable real-time monitoring, predictive analytics and efficient resource management, directly improving productivity, reducing delays and minimizing costs [11], [8]. Intelligent Safety Management emerged as another high-priority application, highlighting how IoE systems can continuously monitor site conditions, detect hazards, and enhance worker safety [12]. Furthermore, quality monitoring and defect management demonstrates the potential of IoE technologies to provide accurate, data-driven insights for inspections, defect detection, and quality assurance [16]. These findings demonstrate that IoE technologies offer versatile, high-impact applications across construction operations. Technological and organizational enablers are the primary determinants of adoption, while environmental factors such as regulatory compliance, site-specific conditions and industry trends, though moderately influential, remain important considerations. Therefore, prioritizing these key drivers and application areas can support Nigerian construction organizations in effectively leveraging IoE solutions to improve efficiency, safety and data-driven decision-making across projects.

6. Implications of findings

The results of this study provide meaningful insights for engineering managers overseeing the adoption of emerging technologies in construction, particularly Internet of Everything (IoE) systems. By highlighting the critical drivers from the Technology–Organization–Environment (TOE) perspective, this research identifies the technological, organizational, and environmental factors that most strongly influence successful IoE integration. From a practical standpoint, engineering managers are encouraged to prioritize strategic investment in IoE technologies. This extends beyond procuring hardware and software as it also includes building internal capabilities, developing skilled personnel and creating workflows that fully leverage connected devices, sensors and real-time analytics. Establishing dedicated roles or teams for IoE management, data analysis, and system integration can help organizations maximize the value of these technologies and enhance project outcomes. Leadership and organizational culture are equally critical. The study underscores that top management commitment, support for innovation and a culture that embraces technological change significantly affect IoE adoption. Engineering managers can respond by promoting leadership development, fostering an innovation-friendly environment and implementing training programs that enhance staff competencies in IoT, predictive analytics, and digital project management.

Regarding practical applications, the study identifies predictive maintenance & asset optimization, real-time project management (digital twin), supply chain & material logistics, and intelligent safety management as high-impact areas for IoE deployment. Engineering managers can focus on these applications to achieve immediate benefits, such as improved operational efficiency, cost reduction, enhanced safety and evidence-based decision-making. Additionally, managers should remain attentive to emerging use cases and continuously evaluate how new IoE applications can address evolving construction challenges. Finally, the study demonstrates the utility of Fuzzy Synthetic Evaluation (FSE) as a tool for addressing complex and uncertain decision-making environments. Engineering managers can leverage FSE to systematically assess multiple adoption drivers, weigh their relative importance and make informed decisions regarding technology deployment. Integrating such decision-support tools can enhance strategic planning, reduce risks and ensure that IoE adoption aligns with organizational goals and project requirements.

7. Conclusion

This study applied the Technology–Organization–Environment (TOE) framework to investigate the key drivers influencing the adoption of Internet of Everything (IoE) technologies within construction organizations in Lagos State, Nigeria. The results indicate that technological and organizational factors are the primary determinants of adoption. Technological drivers such as the reliability and effectiveness of IoE systems, cost-effectiveness, ease of use, maintainability, and seamless integration with existing workflows were found to be particularly influential. Organizational factors, including top management commitment, a culture that supports innovation, and the availability of skilled personnel with IoE expertise, also play a critical role, as highlighted through the Fuzzy Synthetic Evaluation (FSE). In addition to identifying adoption drivers, the study explored the most impactful areas of IoE application. These include intelligent safety management, predictive maintenance and asset optimization, real-time project management through digital twin systems and supply chain and material logistics. These applications represent high-value opportunities where IoE technologies can enhance operational efficiency, safety, and decision-making within construction projects. These findings demonstrate that a deliberate focus on these technological and organizational dimensions can significantly improve the likelihood of successful IoE integration.

From a practical perspective, these insights provide construction professionals, engineering managers, and policymakers with a roadmap for strategic planning and resource allocation. By understanding which drivers and applications are most critical, organizations can prioritize investments, develop targeted training programs, and implement processes that maximize the value of IoE technologies. Such strategic adoption can contribute to enhanced project efficiency, cost optimization, improved safety outcomes, and overall competitiveness within the Nigerian construction sector. While this study offers valuable contributions, several limitations should be acknowledged. The research was confined to construction organizations within Lagos State, which may limit the generalizability of the findings. Future research could expand to other regions or countries to provide a broader perspective on IoE adoption in construction. Additionally, as a quantitative study, it primarily captures measurable perceptions and ratings. Incorporating qualitative approaches in future work could provide richer insights into the experiences, attitudes, and challenges faced by professionals in implementing IoE solutions. Such mixed-method research could uncover additional contextual or behavioral factors influencing adoption and further strengthen strategies for leveraging IoE in construction.

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