

Internet of Things Technologies Utilization Assessment for Construction Site Management in Nigeria

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ABSTRACT

Technology has revolutionized many sectors of the global economy, and the Nigerian construction sector is no exception. However, the extent to which Internet of Things (IoT) technologies are adopted within the Nigerian construction industry still remains underexplored, hence necessitating this study to assess the utilization of IoT technologies for construction site management in the Nigerian construction industry. The study specifically examined the extent of adoption of IoT technologies in construction site management practices and to determine the impact of adoption of IoT technologies on construction site management practices. The study was conducted in major Nigerian cities, using a descriptive survey design. The population of the study consisted of 10,000 construction professionals, and a sample size of 385 professionals, arrived at by applying the Cochran formula. Data were collected through structured questionnaire, and were analyzed using a combination of descriptive and inferential statistics, and hypotheses were tested at a 5% level of significance. The results revealed that the integration of IoT had a clear and statistically significant impact on how construction sites are managed ($R = .461$, $R\text{-Square} = .231$, $F = 37.323$, $P\text{-value} < .05$). The study concluded that targeted investments in workforce training, cost-effective solutions, and supportive organizational policies are essential to accelerate IoT adoption and realize its full benefits in Nigerian construction site management. Sequel to this, among others, it was recommended that firms should begin the adoption of IoT which is still very low, with IoT solutions they are already familiar with, such as drones, GPS trackers, RFID, and surveillance systems, before transitioning to more advanced IoT tools like automated sensors, wearables, and predictive monitoring systems.

Keywords: Internet of Things (IoT) technologies, Construction Site Management, DronesGPS Trackers, Surveillance Systems

1. INTRODUCTION

The Internet of Things (IoT) is revolutionizing various sectors by embedding internet connectivity into physical devices, enabling real-time data collection and analysis. Its integration in various industries has significantly transformed operational efficiency and data management, and the construction sector is increasingly exploring its potential applications in construction site management (Maqbool, Saiba and Ashfaq, 2023). With the ability to connect devices, equipment, and sensors to a centralized network, IoT offers opportunities for real-time data monitoring, remote control, automation and predictive maintenance in construction operations (Teizer, Wolf, Golovina, Perschewsk, Propach, Neges, and König, 2017). According to Sivakumaran, Rathnasinghe, and Seneviratne, (2021), IoT systems can facilitate the monitoring of construction activities, thereby improving productivity and reducing operational costs. Therefore, understanding how it can be effectively utilized in construction site management is crucial for optimizing project performance and enhancing productivity.

Construction site management in developing countries such as Nigeria continues to face numerous challenges, including project delays, cost overruns, safety hazards, material wastage, theft and inefficient resource utilization. These challenges are often associated with inadequate communication, limited visibility into project progress, and reactive decision-making processes (Turner and Townsend, 2026). While IoT has proven globally to address these challenges through proactive monitoring, data-driven decision-making, and seamless communication among project teams (Rane, 2023), the non-implementation and poor integration of IoT in many Nigerian construction sites seem to have worsened these persistent problems. Oke, Arowoia, and Akomolafe (2022) opine that the implementation of IoT in construction leads to better resource management, reduced wastage, and timely project delivery.

Project management in construction benefits immensely from IoT through improved scheduling, monitoring and resource allocation. Real-time data collected from IoT devices can be analysed to optimize project timelines and resource deployment. Katiyarand Kumar (2021) emphasize that IoT can facilitate better decision-making by providing accurate and timely information about site conditions and project progress. This data-driven approach can help project managers to anticipate potential issues and take corrective actions proactively. However, the absence of IoT-driven real-time monitoring in many construction projects within the study area has resulted in inaccurate progress tracking, poor coordination, and delayed identification of project risks, which often leads to cost overruns and project abandonment (Iroha, Watanabe, and Satoshi, 2024).

The applications of IoT in construction site management encompass diverse functionalities, such as monitoring equipment performance, tracking material deliveries, ensuring compliance with safety regulations, and managing workforce productivity. Through the deployment of IoT-enabled sensors and data analytics tools, construction managers can access valuable insights into project status, identify potential bottlenecks, and make informed decisions to optimize resource utilization (Zabidin, Shahrudin, and Belayutham, 2022). Despite these numerous benefits, the adoption of IoT in construction faces several barriers, including high initial costs, data security concerns, and a lack of technical expertise. Chung, Tariq, Mohandes, and Zayed, (2023) points out that while IoT technologies are becoming more affordable, the investment required for a full-scale implementation can be substantial. Additionally, issues of data security and cyber threats have discouraged many firms from embracing IoT fully. As a result, the slow adoption and weak integration of IoT in the Nigerian construction industry continue to hinder innovation and digital transformation in site management practices. The lack of smart monitoring systems in many Nigerian construction firms as a result of seeming slow IoT utilization has continued to encourage inefficient manual record-keeping, poor inventory control, equipment breakdowns, and weak performance evaluation systems. It is against this backdrop that this study aims to assess the utilization of internet of things (IoT) technologies for construction site management in Nigeria. To achieve this aim, the study:

- I. Examined the extent of adoption of IoT technologies in construction site management practices within the study areas.
- II. Determined the effect of adoption of IoT technologies on construction site management practices within the study areas.

2. LITERATURE REVIEW

Internet of Things (IoT)

The concept of the Internet of Things (IoT) traces back to the early 1980s when the idea of connected devices began taking shape. The first recognized IoT device was a modified Coke machine at Carnegie Mellon University, which provided inventory data and informed users if drinks were cold. However, the term "Internet of Things" was coined much later, in 1999, by Kevin Ashton, a British technology pioneer. Ashton introduced the term while working on supply chain optimization at Procter and Gamble, envisioning a network of sensors that could track goods and automate processes (Dhivya and Apoorva, 2018). He described IoT as: "If we had computers that knew everything there was to know about things (using data they gathered without any help from us) we would be able to track and count everything, and greatly reduce waste, loss, and cost. We would know when things needed replacing, repairing or recalling, and whether they were fresh or past their best."

The IoT concept was coined by a member of the Radio Frequency Identification (RFID) development community in 1999, and it has recently become more relevant to the practical world largely because of the growth of mobile devices, embedded and ubiquitous communications, cloud computing and data analytics (Goundaret *et al.* 2021). IoT is already becoming common in our homes in the form of smart heating systems, smart meters for electricity and entertainment devices like the Amazon Echo and Google Home. Fitness devices also bring the IoT to our wrists to allow us to track our exercise routines, while smart cars are becoming more common, even if self-driving cars remain a long way off.

By definition, Internet of Things (IoT) refers to a network of interconnected physical devices embedded with sensors, software, and other technologies that enable them to collect, exchange, and act on data without requiring human intervention. These devices, ranging from household gadgets to industrial machinery, are linked through the internet, fostering automation, efficiency, and intelligent decision-making. IoT is a paradigm in which objects equipped with sensors, actuators, and processors communicate with each other to serve a meaningful purpose (Sethi and Sarangi, 2017).

There are four main components of an IoT system

1. The Thing itself (the device or gadget that ought to be a sensor or actuator),
2. The local network (this is the gateway, which translates proprietary communication protocols to Internet Protocol),
3. The Internet and cloud, and
4. Back-end services (enterprise data systems, or PCs and mobile devices)

Application of Internet of Things (IoT) in the Construction Industry

The use of (IoT) has been a major tool in revolutionizing the construction industry by enhancing efficiency, safety, and project management through real-time data collection and analysis. One of the primary applications of IoT in construction is asset tracking. IoT devices equipped with Radio Frequency Identification (RFID) tags or Global Positioning System (GPS) capabilities allow for real-time monitoring of tools and equipment, reducing the risk of theft and loss while optimizing resource allocation on job sites. This capability significantly minimizes downtime and enhances overall productivity. The real-time tracking allows for better resource control on construction sites, as the project managers can quickly identify the location and availability of tools. As a result, this leads to minimized downtime (when work is halted due to unavailable equipment) and enhances overall productivity by ensuring that projects progress smoothly and efficiently (Gujar and Singh, 2024).

The statement emphasizes the critical role of Wearable IoT such as smart helmets and vests, which are equipped with sensors that monitor workers' health metrics, including heart rate and body temperature, as well as environmental conditions like air quality and temperature extremes have been used in enhancing construction sites in developed societies. By continuously collecting this data, wearable devices can detect hazardous situations, such as toxic gas exposure or unsafe temperature levels, and alert personnel immediately. This proactive approach to safety helps prevent accidents before they occur (Patel *et al.* 2022). These wearables have also been used in monitoring the physical exertion levels to prevent heat stress or fatigue-related incidents. By the provision of real-time insights into both worker health and environmental conditions, IoT wearables significantly enhance safety protocols on construction sites, ultimately reducing the risk of injuries and fatalities. This integration of technology into safety practices represents a transformative shift in how construction companies prioritize worker well-being (Ibrahim *et al.* 2025).

Internet of Things (IoT) play a significant role in facilitating just-in-time provisioning and predictive maintenance within the construction industry. Just-in-time provisioning involves the use of IoT sensors to monitor inventory levels, ensuring that materials arrive exactly when needed on-site. This minimizes waste and reduces storage costs, as it prevents overstocking and shortages that can delay project timelines (Allioui and Mourdi, 2023). On the other hand, predictive maintenance leverages IoT sensors installed on machinery to continuously assess equipment health. By collecting and analysing performance data, these sensors can identify potential issues before they escalate into costly breakdowns. This proactive maintenance strategy not only extends the lifespan of equipment but also ensures that machinery operates efficiently, thereby reducing downtime and enhancing overall productivity. Together, these IoT

applications streamline operations in construction, leading to more efficient project management and cost savings while improving safety and resource allocation (Murtaza *et al.* 2024).

The integration of IoT technology has been integrated with Building Information Modelling (BIM) in creating digital twins, which are virtual representations of physical structures. This integration enables continuous monitoring and analysis of a building's performance throughout its lifecycle, from design and construction to operation and maintenance. By utilizing real-time data collected from IoT sensors, digital twins simulate actual conditions, allowing stakeholders to make informed decisions regarding design modifications and maintenance strategies (Nguyen and Adhikari, 2023).

Construction Site Management

In Nigeria, the construction industry has been a key driver of infrastructure development, and as such effective site management is essential in achieving project objectives within the constraints of time, cost, and quality. Therefore, construction site management is very essential for infrastructure development and the success of any construction project. Construction site management involves overseeing various aspects of a project which include cost, time, and quality control (Ushie, Muoka, Mogbo, Bamgbade, Obianyo, and Mambo. (2024).

The challenges faced, such as project delays and cost overruns, can be mitigated through systematic management practices (Yahya, Abba, Yassin, Omar, Sarpin, and Orbintang, 2024). One of the core aspects of site management is on the management of resources, this deals with the efficient allocation and utilization of labour, materials, and equipment. This includes monitoring inventory, coordinating deliveries, and maintaining equipment to minimize downtime as proposed by Garba, Olaleye, and Jibrin (2016). From their study, it was stated that material waste in construction contributes approximately 30-35% of project cost; thereby leading to material loss and project cost overruns. Lack of concern by Governments and developers globally and Nigeria in particular is continuously affecting the use of these resources. In addition, Unegbu, Yawas, and Dan-asabe (2023) observed that ineffective scheduling and risk management lead to delays and cost overruns. Efficient project scheduling is a critical practice, where managers develop timelines using tools like Gantt charts or project management software, enabling real-time tracking of progress and adjustments when necessary (Cross, 2019). But the implementation of a robust project management practice can mitigate risks and improve performance of most projects in the country.

According to Bhattacharya (2023) for the effective planning and resource utilization of a project there must be an optimization of resources. Resource optimization in a construction site deals with the strategic planning, allocation, and efficient utilization of labour, materials, equipment, and finances to achieve the project aims with minimal waste. This process is critical for ensuring cost-effectiveness, improving productivity, and delivering projects within the stipulated timeframe, especially in resource-constrained environments (Jimoh, 2012). Labour optimization involves aligning workforce skills with project demands in order to enhance productivity. This includes proper task scheduling, adequate training, and implementing performance monitoring systems. Olugbenga and Abiodun (2020) showed that workforce inefficiencies in Nigerian construction sites can be mitigated through effective labour management practices, such as the use of time-tracking software and clear communication channels. The focus of material optimization is on minimizing wastage and ensuring timely procurement of quality materials. Implementing just-in-time delivery strategies and material tracking systems reduces overstocking and loss due to spoilage or theft (Albert, Shakantu, and Ibrahim (2018). Additionally, digital tools like Building Information Modelling (BIM) had been used in facilitating accurate resource estimation and inventory management. And equipment optimization involves proper scheduling, routine maintenance, and effective utilization of machinery to avoid underuse or downtime. For instance, IoT devices have been integrated in real-time equipment monitoring has proven to enhance operational efficiency (Ingole, 2022).

Effect of Internet of Things(IoT) on Project Performance Metrics in Nigeria

The impact of the Internet of Things (IoT) on project performance metrics in Nigeria's construction industry is substantial, influencing various aspects such as efficiency, cost management, safety, and quality control. One key performance metric that IoT significantly enhances is project efficiency. By integrating IoT devices such as sensors

and smart equipment, construction firms can monitor real-time data related to project progress and resource utilization. For example, IoT-enabled tools can track the location and usage of machinery, ensuring that resources are allocated optimally and reducing idle time (Katiyar and Kumar, 2021). This real-time visibility allows project managers to make informed decisions quickly, ultimately leading to improved timelines and enhanced productivity on construction sites.

Another critical metric positively impacted by IoT is cost management. The ability to collect and analyse data in real-time enables construction companies to identify inefficiencies and areas where costs can be reduced. For instance, predictive maintenance powered by IoT technology can alert teams about potential equipment failures before they occur, allowing for timely repairs that prevent costly downtime. According to a study published it was observed that implementing IoT solutions in construction can result in cost savings of up to 20% by minimizing equipment breakdowns and optimizing resource allocation (Tunji-Olayeni *et al.* 2017). Furthermore, IoT applications can enhance procurement processes by ensuring that materials are delivered just-in-time, thus reducing storage costs and waste.

Safety is another vital performance metric that benefits from IoT integration. Construction sites are inherently hazardous environments, and the application of IoT technologies can significantly enhance worker safety. Wearable devices equipped with sensors can monitor workers' health metrics and environmental conditions, providing alerts for hazardous situations such as toxic gas exposure or unsafe temperature levels. A recent report highlighted that implementing IoT solutions for safety monitoring could reduce workplace accidents by up to 30% (Ibrahim *et al.* 2025). By fostering a safer working environment, companies not only protect their workforce but also minimize potential liabilities associated with workplace injuries.

Quality control is an essential metric that IoT can influence positively. The use of IoT devices allows for continuous monitoring of construction processes and materials, ensuring compliance with quality standards throughout the project lifecycle. For instance, smart sensors can detect variations in material properties or environmental conditions that may affect the integrity of the construction work. This capability enables immediate corrective actions to be taken before defects occur, thus maintaining high-quality standards in project delivery. Study showed that integrating IoT technologies into quality control processes could lead to a reduction in rework rates by up to 25%, thereby enhancing overall project outcomes (Khan and Rashid, 2024).

The application of IoT in Nigeria's construction industry has been found to have a profound impact on various project performance metrics including efficiency, cost management, safety, and quality control. By leveraging real-time data and advanced analytics provided by IoT technologies, construction firms can optimize their operations significantly. As Nigeria continues to embrace digital transformation within its construction sector, the potential benefits of IoT will likely drive further improvements in project performance and contribute to the industry's overall growth.

Technology adoption theories

The adoption of the Internet of Things (IoT) in construction site management can be analysed through various theoretical lenses that explain technological adoption, organizational behaviour, and innovation diffusion. Kelly and Palaniappan (2023) stated that one widely applied theory is the Technology Acceptance Model (TAM), developed by Davis (1989), which posits that perceived usefulness and perceived ease of use are the primary determinants of technology adoption. In the construction industry, site managers and stakeholders may be hesitant to integrate IoT solutions if they perceive them as complex or offering minimal benefits. However, as awareness increases and firms recognize the advantages of real-time monitoring, predictive maintenance, and enhanced safety, the likelihood of IoT adoption grows (Okeet *et al.* 2022).

Many construction firms in Nigeria are hesitant to adopt IoT due to concerns about technical complexity, high costs, and lack of expertise. By applying TAM, organizations can focus on enhancing user training, demonstrating the efficiency benefits of IoT tools, and simplifying technology interfaces to improve adoption rates. As the proposed IoT framework is aimed at improving construction professionals' perception of the usefulness and ease of use of IoT systems, which will directly influence their acceptance and implementation on construction sites.

Diffusion of Innovation (DOI) Theory (Rogers, 2003), another theoretical framework explains how new technologies spread within an industry. According to this theory, the adoption of IoT in construction site management depends on five key factors: relative advantage, compatibility, complexity, trialability, and observability. In Nigeria, the slow adoption of IoT can be linked to infrastructural limitations, cost concerns, and resistance to change among industry stakeholders. However, early adopters who successfully integrate IoT into their site management processes serve as catalysts for wider industry adoption, showcasing the potential benefits of improved project monitoring, automated data collection, and enhanced decision-making. Through successful case studies and pilot projects, firms can observe how IoT enhances project monitoring, site safety, and resource management, thereby increasing the willingness of other firms to adopt similar technologies.

The Technology-Organization-Environment (TOE) Framework proposed by Tornatzky and Fletcher (1990) also provides insights into IoT adoption by considering three critical dimensions: technological, organizational, and environmental factors. From a technological perspective, the availability of IoT infrastructure and technical know-how influences adoption. Organizational factors such as leadership commitment, financial investment, and workforce readiness also play a crucial role. Additionally, external influences such as government regulations, industry standards, and market competition shape how construction firms implement IoT solutions. In Nigeria, addressing these factors through strategic policies and capacity-building initiatives can facilitate widespread adoption.

And the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkateshet *al.*, 2003) integrates elements from multiple technology adoption theories to provide a comprehensive understanding of user behaviour. The UTAUT model suggests that performance expectancy, effort expectancy, social influence, and facilitating conditions determine the likelihood of IoT adoption in construction. In Nigerian construction sites, external pressures from regulatory bodies, clients, and industry associations can drive adoption, while inadequate technical support and infrastructure remain significant barriers. By addressing these concerns, construction firms can develop a structured approach to IoT implementation, improving efficiency, safety, and sustainability in site management.

Behavioural theories

Behavioural theories play a crucial role in exploring how human attitudes, perceptions, and external influences shape decision-making and technology acceptance, in this case IoT on construction site management. Since the successful deployment of IoT in construction sites depends on the willingness of managers, engineers, and workers to embrace digital transformation, behavioural theories provide insights into the factors that influence adoption rates. One of such behavioural theory is the theory of planned behaviour (TPB) which was proposed by Ajzen in 1991. According to this theory, an individual's decision to adopt a new technology is shaped by three key factors which are; attitude toward the behaviour, subjective norms, and perceived behavioural control (Limet *al.* 2023). These elements help explain why some construction professionals embrace IoT solutions, while others remain hesitant.

1. **Attitude Toward IoT Adoption:** Attitude refers to the positive or negative perception of IoT technology in construction site management. If construction managers, engineers, and workers perceive IoT as beneficial improving efficiency, reducing costs, and enhancing safety, they are more likely to adopt it. However, scepticism about high implementation costs, cyber security risks, and lack of expertise may result in a negative attitude, slowing down adoption (Díaz et al., 2020).
2. **Subjective Norms in the Construction Industry:** Subjective norms relate to social influences and industry expectations. In Nigeria, where construction site management often follows traditional rather than digital methods, the pressure from industry leaders, regulatory bodies, and peers can encourage or discourage IoT adoption. If clients, competitors, or government policies emphasize the importance of digital transformation, firms are more likely to integrate IoT to stay competitive (Oke and Arowoia, 2021)
3. **Perceived Behavioural Control (PBC) and IoT Implementation:** PBC reflects an individual's perception of their ability to adopt and use IoT solutions effectively. If construction professionals believe they have adequate resources, technical expertise, and institutional support, they are more likely to implement IoT in site management. However, challenges such as limited ICT infrastructure, inadequate funding, and lack of skilled personnel can create barriers, making adoption seem difficult (Adebisi *et al.* 2023).

Extent of Adoption of IoT Technologies in Construction Site Management

Adebiyi et al. (2023) conducted a study in Lagos State, Nigeria, to examine the application of digital technologies within the construction industry. The findings revealed that the adoption of IoT technologies remains relatively low, with their usage largely limited to basic safety monitoring and reporting systems. The study further observed that many construction firms had not fully integrated IoT tools into routine construction site management practices, indicating that adoption is still at an early and experimental stage.

Chen, Ha, Tai and Chang (2020) investigated the willingness and extent of adoption of IoT technologies within Taiwan's construction industry. The study applied the Technology Acceptance Model (TAM) and Theory of Planned Behaviour (TPB) using survey responses from construction practitioners. Findings revealed that the adoption of IoT technologies in construction projects was moderate, especially in areas such as construction monitoring, safety management, and material tracking. However, adoption of more advanced IoT-integrated systems remained limited due to concerns about complexity, cost, and technical integration. The study concluded that organisational support and perceived usefulness strongly influence the extent of IoT adoption in construction site management.

Owolabi and Olufemi (2018) carried out a nationwide study in Nigeria to examine the use of ICT within the construction industry. Their findings showed that the extent of technology adoption is significantly influenced by organisational characteristics, particularly company size. Large construction firms were found to adopt ICT tools more readily than small and medium-sized enterprises, largely due to better financial capacity and access to technical expertise.

Waqar, Khan, Shafiq, Skrzypkowski, et al. (2023) assessed the extent of adoption of IoT technologies for safety management in small construction projects in Malaysia. Using Structural Equation Modelling (SEM), the researchers analysed survey data collected from construction stakeholders. The study revealed that IoT adoption was still at a developing stage, although some firms had begun implementing smart sensors, wearable devices, and real-time monitoring systems. The findings indicated that larger firms demonstrated greater adoption levels than small and medium-sized enterprises. The study concluded that despite recognition of the benefits of IoT technologies, adoption remains constrained by high costs, insufficient technical knowledge, and lack of organisational readiness.

Collectively, the reviewed studies showed that the extent of adoption of IoT technologies in construction site management is still low to moderate across many developing countries. Similarly, Adebiyi et al. (2023) and Waqar et al. (2023) found that IoT adoption remains at an early or developing stage, with most firms mainly using basic technologies such as smart sensors, wearable devices, and monitoring systems for safety management. Also, Chen, Ha, Tai, and Chang (2020) revealed that although construction firms moderately adopted IoT technologies for monitoring, safety, and material tracking, the use of more advanced IoT-integrated systems was still limited due to issues such as cost, complexity, and technical integration challenges. In the same vein, Owolabi and Olufemi (2018) and Waqar et al. (2023) observed that larger firms adopted digital technologies more readily than small and medium-sized enterprises because of better financial strength, organisational support, and technical expertise. The reviewed studies are similar to the current study because they all examined the extent of IoT or digital technology adoption within the construction industry and identified factors influencing adoption. However, they differ from the current study in terms of location, methodology, and specific focus, as some studies focused on ICT generally, safety management, or behavioural theories of adoption, while the current study specifically focuses on IoT technologies in construction site management within the Nigerian construction industry.

Effect of IoT Adoption on Construction Site Management Practices

Oke et al. (2024) conducted a study in Nigeria to examine the effects of IoT adoption on construction project performance. The findings revealed that IoT adoption significantly improves safety, security, productivity, and overall project performance. The study concluded that IoT technologies enhance real-time monitoring, risk control, and operational efficiency on construction sites.

Similarly, Okpo et al. (2023) investigated the influence of digitalisation on construction project performance among firms operating in Abuja, Nigeria. The findings showed that digital tools positively influence project quality, time, and cost performance, with quality performance recording the strongest impact. This suggests that digital technologies contribute meaningfully to improved construction outcomes, even when adoption levels are moderate.

Vincent et al. (2022), in Enugu State, also demonstrated that the application of sensor technologies enhances safety management on construction sites by improving hazard detection and monitoring of site conditions.

Althoey et al. (2024) explored the influence of IoT implementation on resource management in construction projects. The empirical study found that IoT adoption improved material management, equipment utilisation, workforce coordination, and communication efficiency on construction sites. The study further revealed that IoT technologies enabled real-time data collection and monitoring, leading to better resource planning and reduced operational waste. The authors concluded that IoT implementation significantly enhances construction site management efficiency and project control.

Oke, Arowoiya, and Akomolafe (2022) investigated the influence of Internet of Things (IoT) applications on construction project performance in Nigeria. The study adopted a quantitative survey approach involving construction professionals such as architects, engineers, builders, and quantity surveyors. Findings revealed that IoT adoption significantly improved construction site management practices through enhanced communication, real-time monitoring, equipment tracking, workforce coordination, and safety management. The study also found that IoT technologies contributed to increased productivity, better decision-making, and improved project delivery time. The authors concluded that effective adoption of IoT technologies positively transforms construction site operations and project performance.

Collectively, these studies provide robust empirical evidence that IoT and digital technology adoption significantly enhances construction project performance across multiple dimensions. Oke et al. (2024) and Oke, Arowoiya, and Akomolafe (2022) similarly found that IoT adoption improves real-time monitoring, safety, productivity, and overall site management within the Nigerian construction context, while Okpo et al. (2023) also demonstrated that digitalisation positively influences project quality, time, and cost performance, with quality recording the most pronounced impact. Vincent et al. (2022) further corroborated these findings by showing that sensor technologies specifically enhance safety management through improved hazard detection, and Althoey et al. (2024) also established that IoT implementation strengthens resource management by improving material handling, equipment utilisation, and workforce coordination while reducing operational waste. Although these studies collectively affirm the performance-enhancing potential of IoT technologies, the current study differs in that it moves beyond examining the effects of IoT adoption to developing a comprehensive framework that integrates both the factors influencing adoption and their practical application to construction site management in Lagos State, thereby offering a more structured and context-specific contribution to the existing body of knowledge.

3. METHODOLOGY

Research Design

This study adopted survey method of a descriptive survey research design because of the nature of the study because data about a phenomenon was collected using questionnaire. The study collected data from construction managers, site engineers, project supervisors, safety officers, contractors, and site workers who are directly engaged in the planning, supervision, decision-making, and daily operations of construction sites in selected cities in Nigeria, specifically Lagos State, Abuja (FCT), Port Harcourt (Rivers State), and Anambra State. These locations were selected due to their high concentration of construction activities and their representation of diverse project types and firm sizes within the Nigerian construction industry. These professionals were drawn from registered construction firms, ongoing construction projects, and recognised professional bodies, such as the Council for the Regulation of Engineering in Nigeria (COREN), the Nigerian Institute of Building (NIOB), the Nigerian Society of Engineers (NSE), and the Federation of Construction Industry (FOCI). These sources ensure that respondents possess relevant professional qualifications, practical experience, and direct exposure to construction site management practices. These groups were

selected because of their direct involvement in construction site activities and their crucial roles in understanding how Internet of Things (IoT) technologies can address specific challenges such as safety management, material control, equipment monitoring, and productivity enhancement (Adebiyi et al., 2023). This diverse population ensures that the study captures a holistic view of the opportunities and barriers to IoT implementation in the Nigerian construction industry. The study employs a stratified random sampling technique to ensure a representative sample of the target population. The stratification is based on job roles, company size, and geographic location to capture diverse perspectives from both small- and medium-sized enterprises (SMEs) and large construction firms across urban centres selected areas. This method minimizes bias and ensures that all subgroups within the population are adequately represented (Nwokoye et al., 2022). Within each stratum, respondents are randomly selected to maintain the randomness and reliability of the sample. This approach ensures the study results are generalizable across the Nigerian construction sector. Since the exact number of construction professionals actively involved in site management across Lagos, Abuja, Port Harcourt, and Anambra State is not precisely documented, an estimated population of 10,000 construction professionals was assumed based on records from professional bodies, registered construction firms, and active construction sites in the study areas. The sample size of 385 was determined using the Cochran formula. Structured questionnaire was used to gather quantitative data from construction professionals across the study areas. To ensure the reliability and validity of the instruments, pre-testing was conducted with a pilot group of 20 respondents, including construction managers, site engineers, and IT professionals. Feedback from the pilot test was used to refine question phrasing, eliminate ambiguity, and ensure clarity. Reliability was assessed using Cronbach alpha for the Likert-scale items, aiming for a threshold of 0.7 or higher to confirm internal consistency, and a reliability of .874 was achieved. Validity was ensured through expert reviews, where academic professionals and industry practitioners evaluate the instruments for content relevance, clarity and proper alignment with the research objectives. The data collected for the study were analyzed using both descriptive and inferential and inferential statistics with the aid of the Statistical Package for the Social Sciences (SPSS). For the descriptive analysis, mean scores and standard deviations were calculated to answer the research questions, using a mean threshold of 3.0 as the benchmark for acceptance or rejection. To test the research hypotheses, the study utilized Regression Analysis, to provide a robust assessment of relationships between variables at a 5% significant level.

4. RESULTS AND DISCUSSIONS

Assessment of the state of construction site management by the firms

The analysis in chapter four was done using a total of 345 copies of questionnaire, because all the 385 copies distributed across the study areas (FCT, Lagos State, Rivers State and Anambra State) were not fully collected and filled, hence, the study used 91% of the sample size of the study.

Table 1: Extent of adoption of IoT technologies in construction site management practices

S/N	Question Items	VGE (5)	GE (4)	SE (3)	LE (2)	VLE (1)	Mean	SD
1	To what extent has your firm adopted IoT technologies for monitoring site activities and project progress?	14	35	118	113	65	2.48	1.037
2	To what extent are IoT-based sensors used to collect data on construction site conditions (e.g., temperature, vibration, humidity)?	11	28	112	124	70	2.38	.999
3	To what extent does your firm use IoT devices for tracking materials, tools, and equipment on site?	22	43	89	128	63	2.52	1.118
4	To what extent has your firm integrated IoT technologies for improving worker safety and site security?	20	70	110	98	47	2.76	1.100
5	To what extent are IoT platforms or software systems used for project coordination and scheduling?	10	23	154	132	26	2.59	.838

6	To what extent is IoT data utilized for decision-making in daily site management activities?	15	33	121	109	67	2.48	1.046
7	To what extent has your firm adopted IoT for remote supervision or control of construction machinery and equipment?	55	77	93	80	40	3.08	1.247
8	To what extent has IoT been applied to improve communication and collaboration among site workers and managers?	25	84	103	91	42	2.88	1.129
9	To what extent does your firm use IoT to monitor compliance with project timelines and budgets?	40	103	77	69	56	3.01	1.271
10	To what extent has your firm invested in training staff for the effective use of IoT technologies?	40	70	118	94	23	3.03	1.099

Keys:

To a Very Great Extent (VGE); To a Great Extent (GE); To Some Extent (SE); To a Little Extent (LE); To a Very Little Extent (VLE)

Table 1 sought to determine the extent to which construction firms within the study areas have adopted Internet of Things (IoT) technologies for construction site management, based on the 345 questionnaires analyzed. Using a mean threshold of 3.0 as the benchmark for acceptable adoption, the results show that the extent of adoption remains generally low across most IoT applications. Only three items recorded mean values above the threshold, indicating limited but emerging adoption in specific areas. These include the use of IoT for remote supervision or control of machinery and equipment, which achieved a mean score of 3.08, suggesting that some firms are beginning to explore IoT-enabled remote operations. Similarly, the use of IoT to monitor compliance with project timelines and budgets recorded a mean score of 3.01, indicating that a small proportion of firms apply IoT tools to support project monitoring. In the same vein, investment in staff training for effective IoT usage showed a mean value of 3.03, pointing to modest efforts by firms to build internal capacity for IoT integration.

However, the remaining indicators fell below the mean threshold, revealing that adoption is still insufficient in most critical areas. The use of IoT to monitor site activities and project progress had a low mean of 2.48, while the use of IoT-based sensors to collect environmental and site condition data recorded an even lower mean of 2.38, indicating very limited sensor-based monitoring. IoT adoption for tracking materials, tools, and equipment also remained low with a mean score of 2.52, just as IoT integration for improving worker safety and site security showed a mean value of 2.76, which is below the expected level. In addition, the use of IoT platforms for coordination and scheduling (mean = 2.59), the utilization of IoT data for decision-making in daily site activities (mean = 2.48), and the application of IoT to enhance communication and collaboration among site personnel (mean = 2.88) all fell short of the benchmark. Overall, the results from Table 4.3 indicate that while awareness of IoT technologies is relatively high among respondents, the actual extent of adoption within construction site management remains low, suggesting that the industry is still at an early stage of IoT implementation.

Table 2: Effect of integrating IoT technologies on construction site management practices

S/N	Question Items	VGI	GI	MI	LI	VLI	Mean	SD
1	How much impact has IoT made on the efficiency of construction site management?	45	102	130	51	17	3.31	1.034
2	What impact has IoT brought to real-time monitoring of site activities?	51	147	36	74	37	3.29	1.257
3	How greatly has IoT enhanced safety and security conditions on construction sites?	82	139	27	64	33	3.21	1.262
4	What degree of impact has IoT had on communication and coordination among project teams?	89	122	70	44	20	3.63	1.165
5	How significantly has IoT contributed to meeting project	104	140	58	26	17	3.54	1.141

	deadlines and reducing delays?								
6	What impact has IoT integration had on data accuracy and informed decision-making?	88	138	50	49	20	3.65	1.172	
7	How far has IoT helped in tracking and managing materials and equipment effectively?	92	140	63	33	17	3.74	1.102	
8	How much cost efficiency has IoT contributed through reduced waste and better resource use?	85	132	85	25	18	3.70	1.079	
9	What impact has IoT had on maintaining quality control and compliance standards?	45	143	69	65	23	3.35	1.127	
10	How strongly has IoT improved workforce productivity and workflow organization on site?	78	137	56	44	30	3.55	1.217	
11	What level of impact has IoT made in resolving on-site problems quickly and accurately?	100	144	41	34	26	3.75	1.192	
12	How level of impact hasIoTmade in strengthening documentation and record management on construction sites?	92	103	74	50	26	3.54	1.236	
13	How greatly has IoT increased transparency and accountability in site operations?	101	167	43	22	12	3.96	.941	
14	What overall impact has IoT made on the successful performance of construction projects?	101	162	52	19	11	3.65	1.058	
15	What is the impact ofIoTin promoting innovation and adoption of modern management practices in the construction sector?	97	142	59	25	22	3.77	1.126	

Keys:

Very Great Impact (VGI); Great Impact (GI); Moderate Impact (MI); Little Impact (LI); Very Little Impact (VLI)

Table 2 assessed the effectof integrating Internet of Things (IoT) technologies on construction site management practices within the study areas, based on the responses from the 345 analyzed questionnaires. Using a mean threshold of 3.0 to determine acceptable levels of perceived impact, the results show that all fifteen items recorded mean values above the cutoff, indicating that respondents generally agreed that IoT integration has an impact on various aspects of construction site management. The impact of IoT on strengthening transparency and accountability recorded one of the highest mean scores at 3.96, suggesting that IoT tools significantly enhance openness and improve the traceability of site processes. Similarly, the use of IoT to support real-time problem resolution (mean = 3.75), improve tracking and management of materials and equipment (mean = 3.74), and promote innovation in construction management practices (mean = 3.77) all show that IoT is perceived as highly beneficial in improving operational efficiency.

Furthermore, IoT was rated as having strong impact on data accuracy and informed decision-making, with a mean of 3.65, while its contribution to communication and coordination among project teams also recorded a high mean of 3.63, indicating improved workflow interaction. IoT's role in helping construction firms meet project deadlines and reduce delays (mean = 3.54), enhance documentation and record management (mean = 3.54), and boost workforce productivity (mean = 3.55) further underscores its effectiveness in improving managerial and operational outcomes. The results also show that IoT positively influences site efficiency (mean = 3.31), real-time monitoring of site activities (mean = 3.29), safety and security conditions (mean = 3.21), and overall project performance (mean = 3.65). Even aspects with comparatively lower means, such as IoT's impact on quality control and compliance standards (mean = 3.35), still exceed the threshold, indicating that IoT contributes meaningfully to quality assurance processes.

Overall, the consistently high mean values across all indicators in Table 4.6 demonstrate that IoT integration is perceived to have substantial and wide-ranging impacts on the effectiveness, safety, productivity, coordination, and overall performance of construction site management within the study areas.

5. Test of Hypotheses

Hypothesis One

HO₁: Integration of IoT technologies has no significant impact on construction site management practices within the study areas.

Table 3: Model Summary for Hypothesis Test

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	F	t	Sig.
1	.461 ^a	.231	.230	3.152	37.323	6.227	.000 ^b

Table 3 provides the model summary for the test of hypothesis which examined the effect of IoT integration on construction site management practices. The test yielded an R-value of .461, representing a moderate positive impact. The R-Square of .231 indicates that IoT integration explains 23.1% of the variation in site management effectiveness. With an F-value of 37.323 and a p-value of .000, the model is statistically significant, leading the researcher to reject the null hypothesis (HO₂). This establishes that the integration of IoT has a clear and statistically significant effect on how construction sites are managed.

Table 4: Coefficient for Test of Hypothesis

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1 (Constant)	6.931	1.867		3.713	.000
CSM	.256	.034	.482	7.428	.000

Key:

CSM = Construction Site Management

Table 4 confirms the strength and direction of the effect identified in Table 3. The integration of IoT technologies shows a significant positive effect on site management practices, with a Beta coefficient of .482 and a t-value of 7.428 ($p = .000$). This statistical evidence supports the conclusion that IoT integration directly leads to improvements in site supervision efficiency, real-time monitoring, and resource utilization.

6. Summary of Findings

1. **Extent of adoption of IoT technologies:** the results show that actual adoption remains low to moderate. Only a few construction firms have integrated IoT tools into their operations, and such adoption is mostly limited to basic digital or semi-automated systems. Advanced IoT technologies were found to be minimally deployed, demonstrating that the industry is still at an early stage of IoT implementation. This gap between awareness and adoption suggests structural, financial, or organizational limitations.

2. **Effect of IoT integration:** the study shows that the respondents agreed that IoT improves efficiency in monitoring site operations, enhances safety performance, strengthens documentation processes, supports timely communication, reduces delays, and increases overall productivity.

7. Conclusion

This study examined the adoption and impacts of Internet of Things (IoT) technologies on construction site management practices within the Nigerian construction industry. The findings show that the level of adoption remains low to moderate, indicating a significant gap in implementation. Importantly, the study established that IoT integration has a significant positive impact on construction site management practices, improving monitoring, safety, productivity, communication, and overall project efficiency. In conclusion, this study demonstrates that IoT technologies hold immense potential for transforming construction site management in Nigeria, and the industry's future competitiveness depends on embracing this technological shift. Ultimately, the study affirms that the effective

integration of IoT is not just beneficial but essential for achieving smarter, safer, and more efficient construction site management in the Nigerian construction industry.

8. Recommendations

Based on the findings, the study makes the following recommendations:

- a) Given that the adoption of IoTs in construction site management is currently low to moderate, firms should begin with IoT solutions that are already familiar such as drones, GPS trackers, RFID, and surveillance systems, before transitioning to more advanced IoT tools like automated sensors, wearables, and predictive monitoring systems. To this end, regulatory agencies can publish adoption guidelines to support this phased approach.
- b) Since the study found that IoT has a significant positive impact on site performance, firms should incorporate it into areas such as safety monitoring, equipment tracking, project documentation, communication, and performance evaluation. Policymakers should also support frameworks that ensure standardized, industry-wide IoT implementation to enhance construction site efficiency. All these will streamline and encourage integration of IoTs into construction management practices.

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