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Emerging Trends in the Adoption of Innovative Technologies by Building Firms in Lagos Metropolis

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ABSTRACT

Concerns over the slow pace and work progress among construction companies are pervasive. Nonetheless, technology has the potential to bridge this inefficiency gap. Thus, this study assesses the degree of adoption of innovative technologies during the building production phase with a view to enhancing project delivery. The study's objectives are to evaluate the socio-economic benefits of adopting innovative technologies, establish the degree of satisfaction with the organization's deployment of innovative technologies, and determine the level of technology adoption at the construction stage. The study adopts a survey research strategy to collect data from the respondents in Lagos Metropolis. The population of the study comprises built environment professionals who work in construction micro-small-medium-enterprises (CMSMEs). Criterion based; deliberate, purposive sampling research strategy was deployed to select 109 respondents from the study's population. The statistical tools used for the analysis include frequency, percentages, mean scores, relative implementation index, and ranking. The findings demonstrated that mobile technologies are the most often utilized among the twelve groups of technologies deployed during construction. In contrast, wearable technologies are the least deployed. The study concludes that the current level of technology adoption is low and varies among the CMSMEs. The divergence in technology adoption indicates that CMSMEs in Lagos Metropolis are yet to fully harness innovative technologies to boost construction operations during the building production phase. The study recommends that CMSMEs leverage innovative technologies to enhance the construction phase. This may be accomplished by creating a budget for its uptake and deployment during the building production phase in a bid to unlock its full potential and benefits. Besides, manufacturers of underutilized technologies should amplify product awareness among building firms in Lagos Metropolis. This may be accomplished by organizing training and demonstration programs for construction industry stakeholders on the benefits of deploying the technologies.

Keywords: adoption, building firms, building production management, construction-micro-small-medium-enterprises, emerging trends, innovative technologies, Lagos Metropolis.

1.0 INTRODUCTION

Construction firms leverage digital technologies to optimize procurement processes to increase efficiency and competitiveness. According to Simeon and Soyingbe (2023), organizations rely heavily on their competitive edge over their counterparts to succeed. Thus, incorporating emerging industrial capabilities and technological innovations is critical for increasing the competitiveness of the economy (Tay et al. 2018). Yet, the construction sector is hesitant to adopt modern technologies. Gerbert et al. (2016) and Adekunle et al. (2024) amplify that the construction sector is slow to adapt and deploy emerging technologies. The reasons adduced for the construction sector's non-implementation of these technologies during the building production phase according to Yucel (2018) include insufficient funding, lack of urgency, and IT difficulties. Meanwhile, Alaloul et al. (2020) opine that the high initial cost of purchasing and installing new technologies, the high cost of hiring, training, and retraining staff, as well as the high cost of maintaining such technologies are reasons behind its non-implementation during the building production phase. Building production management, often referred to as the core professional service of a licensed Builder, is the assembly of two or more construction materials, labour, and equipment to erect a building while adhering to the terms of the contract and building codes. Osuizugbo and Ojelabi (2020) buttress that building production management is a discipline that must be practiced efficiently and effectively if projects are to be completed successfully and their objectives, including functional goals, are to be met.

In this regard, studies have demonstrated that technology utilization is crucial to organizations for proper planning and coordination for enhanced project performance. Sepasgozar and Bernold (2013) opine that modern technologies have a proven track record of enhancing construction efficiency, quality, and safety. Sun and Howard (2004) indicate specific phases where technology can be leveraged in construction projects including planning, scheduling site management, and cost estimation. Nonetheless, construction organizations experience low levels of productivity during the building production phase due to the non-deployment of modern technologies. Fitzgerald et al. (2013) confirm this notion that low productivity rates are the result of construction companies' lack of urgency to deploy modern technologies. Moreover, Czarnecki (2017) substantiates that the attainment of triple success objectives of construction projects, and the productivity of construction firms is hinged on the use of technologies in all the phases of construction projects.

The construction industry has experienced tremendous changes in recent times. The sector has received intense attention in the wake of the fulfilment of various construction-related components of the United Nations Development Goals (Oesterreich & Teuteberg, 2016). A few construction technologies have been investigated including cloud computing (Oke et al., 2021), data mining (Aghimien et al., 2019), 3D printing (Shahzad, 2022), Internet of Things (Ibrahim et al., 2023), radio frequency identification (Osunsanmi et al., 2018), sensors (Baghdadi et al., 2019), robotics (Kumar et al., 2020), building information modeling (Martínez-Aires et al., 2018, Oladiran et al., 2023; Oladiran et al., 2024), and blockchain technology (Turk & Klinc, 2017). However, little effort has been made to establish the implementation of these technologies by construction organizations. Furthermore, previous studies have highlighted some benefits organizations derive from adopting technologies. Chen et al. (2020) note that the integration of technologies enables organizations to respond to changing consumer needs and production output. Other benefits according to Aghimien et al. (2018) include the enhancement in production and delivery, project delivery within duration and budget, and propelling sustainable development of projects, among other benefits.

Despite these benefits, little effort has been made to enlighten construction organizations on the socio-economic benefits of adopting these technologies during the building production phase. Also, the present level of implementation of these technologies during the construction production phase has yet to be ascertained in the Nigerian construction clime. Hence, the problem that this study seeks to address is the dearth of investigation on the adoption of innovative technologies during the building construction stage. Therefore, the study aims to establish the degree of implementation of innovative technologies during the building production phase with a view to enhancing project delivery. The objectives of the study are to identify the socio-economic benefits of adopting innovative technologies in the building production phase, establish the degree of satisfaction with the organizations' deployment of innovative technologies, and determine the degree of adoption of construction technologies in the building production phase. The study is significant because it sheds light on the current landscape of CMSMEs adoption of innovative technologies during the building production phase and drives initiatives to enhance their benefits.

2.0 LITERATURE REVIEW

2.1 Trends of Adoption of Innovative Technologies in the Nigerian Building Sector

In the past few decades, the nation's building sector has had a continuous shift, driven by technical breakthroughs, however, acceptance of innovative technologies has been slow. In the early 2000s, the sector depended heavily on manual procedures, with designs often developed using 2D drawings and basic project management tools such as spreadsheets. According to Osuizugbo et al. (2022), the utilization of 2D drawings is vital in assessing the practicability of designs prior to beginning construction. Computer-aided design (CAD) software was being employed in Metropolitan Lagos, providing more exact design capabilities, but it was far from mainstream. Georgiadou (2019) corroborates this assertion that the design, construction, and management of buildings and infrastructure primarily relied on 2D drawings and paper-based documentation. Gholizadeh et al. (2018) add that architects, builders, and engineers have benefited from reduced project time and cost as well as improved quality through the use of 2D CADs. Challenges such as poor infrastructure, restricted internet connection, and high technology purchase prices hampered the widespread use of these technologies, and the business remained primarily reliant on conventional methods throughout this period. There was a considerable shift throughout 2010 and 2015, as people became more aware of new technologies. More construction enterprises, especially larger organizations, began to use CAD software like AutoCAD and Revit, resulting in more precise and adaptable designs. During this period, Building Information Modeling (BIM) was developed, promising to transform project management by giving electronic representations of buildings that incorporated both their physical and functional properties. The design process was improved overall by the advent of BIM technologies, which made it possible to seamlessly integrate AutoCAD drawings with 3D modeling software (Ibrahim et al., 2022). However, BIM adoption was delayed and confined to certain projects. Meanwhile, mobile technology kicked-off to play an essential role in site administration, enabling improved communication and project monitoring. Realizing the value of digital technologies in modernizing businesses, tertiary institutions, professional bodies, and government agencies in the country began to promote the implementation of digital technologies. Universities have integrated these technologies into their engineering and building programs, laying the groundwork for the future. However, the change was slowed by chronic difficulties such as inconsistent power supply and pushback from certain older enterprises that were hesitant to adopt innovative working practices.

Digital technologies became more widely used in construction enterprises between 2016 and 2020. The application of BIM increased, especially in large-scale urban constructions where it became evident how well it could increase productivity, save costs, and minimize errors. According to Gharaibeh et al. (2022), there is widespread agreement that BIM technology holds enormous potential for the construction industry, particularly given the increasing use of BIM in the sector's supply chain. In recent years, BIM technology has evolved beyond simple 3D and 4D to increasingly complex 5D, 6D, and 7D, which are used depending on the project phase (Panteli et al., 2020). Despite its great prospect, Oladiran et al. (2024) conclude that BIM technology is presently being adopted by large construction firms in Lagos Metropolis. Unmanned area vehicles (UAVs), also known as Drones, gained popularity in mapping and site inspections because they provided aerial views that increased the speed and precision of land surveys. Besides, Periola and Obayiuwana (2020) examined how UAVs might reduce worker danger by enabling remote inspections of difficult-to-reach regions, hence improving safety. The rise in interest in prefabrication techniques and modular construction methods can be attributed to the demand for quicker and more affordable building solutions. The potential of 3D printing in building started to be investigated, despite it being in its experimental stage. This assertion was buttressed by Opawole et al. (2022) who discovered the low level of awareness and application of 3D printing technology in Lagos state. The widespread use of cloud-based software for managing projects and cost prediction has streamlined stakeholder communication, particularly in remote areas. According to Oke et al. (2021), cloud computing has been viewed as having the ability to provide sustainability to building endeavors since it utilizes a wide variety of technological innovations, comprehensive procedures, climate change mitigation, creative scheduling, partners, and professional fields. Even with these developments, there were still significant challenges. Oke et al. (2023) buttressed that the Nigerian construction sector has a substantial absence of automation approaches, which raises concerns. These tools were out of reach for many enterprises, especially smaller ones, due to prohibitive prices and technological hurdles. The unreliable internet and power supplies in the nation made it more difficult for these technologies to be implemented successfully. Conventional businesses were frequently hesitant to adopt new practices, opting rather to continue using established methods.

The construction sector underwent a more rapid modernization from 2021 to 2024, mostly because of the COVID-19 epidemic, which highlighted the necessity of digital transformation across all industries, including construction. According to Casini (2021) and Braun et al. (2022), incorporating BIM and related technologies is crucial for solving the complex problems of the COVID-19 pandemic. Cloud computing and digital technologies made it possible for remote work to become indispensable. Therefore, cloud computing is widely used in the construction industry because it enables BIM-based applications and, by providing real-time access to the data pool and computer resources, may assist resolve BIM issues (You & Feng, 2020). Large-scale and government projects were using BIM continually, and businesses needed to use it to remain competitive, especially when bidding on multinational contracts. Additionally, there was an increasing focus on sustainability, with many businesses incorporating eco-friendly and energy-efficient technology into their designs. New construction projects began to incorporate solar panels, energy management technologies, and smart building systems. Current advancements have greatly benefited several aspects of construction, including project planning, design, estimating, and site monitoring (Begić & Galić, 2021). Risk management and project planning began to evolve because of automation and artificial intelligence (AI). Although complete automation in the construction industry, such as the employment of robots for jobs like block laying, remained in its infancy, tools that employed artificial intelligence for predictive analytics assisted firms in making better decisions. According to Ibrahim et al. (2021), internet connection has emerged as the major mode of communication between humans and technology, and as a result, the Internet of Things (IoT) is becoming increasingly significant in almost every industry, including construction. With the application of IoT, building sites can now better manage their resources and cut costs by using it to track materials, monitor equipment, and improve safety. Although it is still in its infancy, blockchain technology has begun to be investigated as a safe solution for managing payments and contracts in building projects. Nonetheless, difficulties continued. The adoption of innovative technologies remained impeded by the same infrastructural problems, including unstable internet and power supplies. Regulation-related obstacles further impeded growth, and the sector also faced a lack of qualified workers to manage these new technologies. There exists a digital gap between larger, well-resourced organizations and smaller ones due to the exorbitant expense of incorporating these technologies. These technologies have become more popular due to several considerations. Rapid urbanization in Lagos metropolitan areas prompted a desire for quicker, more effective building techniques to fulfil the expanding need for infrastructure. Modernization and standardization of construction processes have been promoted by government programs, such as the Nigerian National Building Code, and the Lagos State Physical Planning Permit Authority Regulations. Furthermore, the integration of innovative technologies into Nigerian projects by expatriate firms has compelled indigenous companies to adjust to stay competitive in a global marketplace.

2.2 Benefits Organisation Derives from Adopting Innovative Technologies During Building Production Phase

Organizations derive a plethora of benefits from adopting innovative construction technologies in the building production phase of a project. Some of these benefits are now discussed in this section. Turner et al. (2021) substantiate that the combination of BIM and IoT enables buildings and their components to be considered intelligent entities, delivering information on proper assembly and real-time status during and after construction. The implementation of IoT has yielded significant benefits for the construction industry. These benefits include increased equipment availability via ongoing monitoring, proactive maintenance and repairs to guarantee smooth and efficient operations, and the avoidance of construction delays (Ibrahim et al., 2021).

Furthermore, the use of robots and automation boost efficiency and precision in work such as bricklaying, concrete placing, and site inspection. Forcael et al. (2020) note that robotics has evolved to address difficulties ranging from material transportation route planning to automated systems that perform tasks on construction sites. In addition, exoskeletons, a sort of human-assisted robot, can help prevent accidents on construction sites while also supporting the strength of construction workers during building tasks (Zhu et al., 2021). Moreover, AI algorithms improve decision-making via data analysis, resulting in optimal project timelines, cost savings, and risk avoidance. Osunsanmi et al. (2020) affirm that AI and big data analytics help the construction sector prepare for and forecast predicted site circumstances. Another key benefit of adopting these technologies is improved safety, which is achieved by real-time monitoring of equipment and personnel, assuring adherence to safety protocols, and reducing accidents. Saada and Aslan (2022) accentuate BIM's 8D unique focus which lies in simulating and preventing accidents.

Moreover, researchers and industry practitioners have reported that the use of safety technologies, such as wearable technologies, at various stages of construction projects has the potential to significantly improve construction workers' safety and health (Okpala et al., 2020). Furthermore, the construction industry technologies promote sustainable practices by allowing the utilization of eco-friendly materials, environmentally friendly designs, and smart building systems that are consistent with global environmental goals. One benefit of additive manufacturing according to Oesterreich and Teuteberg (2016) for the building industry is time savings, since structures may be constructed in a matter of days as opposed to weeks, as is the case with conventional construction techniques. The technique can print building structures in situ, and it also has other advantages including fewer workers needed on the construction site and less waste from construction materials (Kozlovska et al., 2021). Moreover, the carbon footprint is lesser than with conventional building methods (Olsson et al., 2021). It also contributes to lower worker exposure to risks related to conventional building projects, which in turn results in lower construction costs (Turner et al., 2021). To this end, construction companies that utilize Industry technologies during the building production phase benefit from increased efficiency, safety, sustainability, and, ultimately, better project outcomes.

2.3 Implementation of Emerging Technologies by Construction Organisations

Construction has traditionally been associated with exhausting approaches, fragmented engagement, and inefficiencies. Nonetheless, with the growth of technological advancements such as the Internet of Things (IoT), Building Information Modelling (BIM), Artificial Intelligence (AI), and Autonomous Robots, the cconstruction industry is experiencing a substantial change towards an increasingly connected and data-driven methodology. Abioye et al. (2021) opine that with the increasing prevalence of IoT sensors and other digital technologies, construction sites are progressively becoming smart working environments. Some of the technologies are now discussed.

2.3.1 Unmanned Area Vehicles (Drones)

Unmanned aerial vehicles (UAVs), also known as Drones, are aerial vehicles that can operate either autonomously by onboard computers or by a human controller and usually come with sensors, cameras, and other cargo. UAVs improve data accuracy, safety, and project management skills by making it possible to survey, map, and monitor construction sites more effectively. Zhou and Feng (2024) add that drones are a crucial component of the digital economy and are becoming increasingly useful due to their quickness, affordability, and ability to operate in unoccupied areas. It can effectively inspect an infrastructure in addition to providing additional benefits (Alzarrad et al., 2022). Its applications in the construction industry have grown significantly in recent years due to its unmatched efficiency over traditional methods (Guan et al., 2022). Furthermore, it covers a wide range of structures such as highways and roads, bridges and overpasses, dams, and other infrastructure facilities (Molina et al., 2023). The use of drones in construction gained dominance in early 2020 by large-scale construction firms for construction project monitoring, site surveying, safety inspections, and mapping. Wahab (2020) substantiate that the primary uses of drone technology in Nigeria are for building surveys, land surveys, topographic mapping, inspections of construction sites, equipment tracking and automation, remote monitoring, integration of laser scanning and aerial photogrammetry, progress reports, and thermal imaging recording. Despite these efforts, there is a low level of UAV technology adoption by CMSMEs in Lagos Metropolitan areas. Some reasons adduced for its low usage according to Yahya et al. (2019) include the exorbitant cost of acquisition and the cost of maintaining and updating the technologies. This was evident in Taibat et al. (2023), who reported that there is a low level of deployment of UAVs among building project sites in Lagos State.

2.3.2 Laser Scanners and Three-Dimensional (3D) Imaging Systems

A laser scanner is a gadget that employs laser technology to identify and measure distances, generally for producing exact coordinates or surface details. Meanwhile, the 3D systems create 3D representations of objects or situations by employing lasers, and cameras. Laser scanners and 3D imaging systems are used in construction to provide exact site surveys, quality control, conflict detection, and as-built documentation, which improves project efficiency and accuracy. Asadi et al. (2019) opined that laser scanning, photogrammetry, and videogrammetry have been utilized in determining the progress of outdoor and indoor building operations by examining 3D models. Several researches have been conducted on BIM-integrated systems with laser scanning technology; the resulting 3D models were compared to 4D BIM models by overlapping, and progress was separated using color bands (Tran & Khoshelham, 2019). The Scan-to-BIM and Scan-vs-BIM are both widely used BIM-based laser scanning apps. As a result, practitioners prefer the Scan-vs-BIM approach over Scan-to-BIM, and it has been used to track MEP components, shoring, formwork, and rebar (Turkan et al., 2014). According to Oke and Arowoiya (2022), laser scanners are key technologies utilized for site monitoring in Lagos state.

2.3.3 Augmented and Virtual Reality (AR & VR)

Technologies like Augmented Reality (AR) and Virtual Reality (VR) improve user experiences by producing completely immersive simulated worlds (VR) or by superimposing digital features onto the actual world (AR). A construction firm uses AR for on-site data overlay and VR for immersive project visualization to increase stakeholder collaboration and improve design accuracy. Kozlovska et al. (2021) opine that both AR and VR technologies are founded on the idea of allowing users to engage in real-time with a virtual environment that mimics the actual world through computer simulation. AR and VR technologies can potentially enhance project knowledge, productivity, communication, and cost-effectiveness. Additionally, they quicken the pace at which new digital technologies are adopted across a range of businesses (Yang et al., 2022). Despite these similarities in application and function. Alizadehsalehi and Yitmen (2021) note that AR technology has gained more popularity over VR in automated progress monitoring because of its capacity to superimpose real-world sceneries with virtual objects as well as precisely integrate with site imaging. These technologies may be employed in a variety of construction applications, including staff training simulation, on-site inspection, and design review (Kozlovska et al., 2021). AR and VR are utilized to check and monitor construction projects. It may be used to collect cost data and manage construction resources throughout project execution (Igwe et al., 2022). The five most common uses of augmented reality in Lagos state according to Oke and Arowoiya (2022) are project planning, monitoring, and modification; project documentation; visualization and simulation of construction processes. The other two aspects are health and safety protocols and real-time information retrieval on-site.

2.3.4 Mobile and Cloud Technologies

These are linked systems, with mobile technology allowing access to apps and data on portable devices and cloud technology providing scalable, on-demand storage and processing resources over the internet. Mobile and cloud technologies boost communication, collaboration, and data management in construction projects by allowing instantaneous updates, file sharing, and remote access to project information. According to Marzano and Martinovs (2020), mobile or cloud technologies involve a process of organizing, processing, and storing data on interconnected, remote servers located on the Internet. Several Authors have mentioned the drivers of this technology. For instance, You and Feng (2020) note that cloud computing is a novel technology that enables communication devices like personal computers and mobile phones to transfer and store data while also doing calculations at third-party data centers. Given that there is less dependence on physical infrastructure, the cloud provides virtualized services for more robust and scalable processing and storage. One of the primary benefits of cloud computing, according to Lu and Cecil (2016), is the usage of sophisticated apps and services that scale dynamically as the number of users grows. Olugboyega et al. (2022) report that site managers in Lagos state view mobile technology (MT) as a personal property and that their main usage of the technology has been for social and private purposes. When operations on construction sites collide with social and private lives, site managers unintentionally use MT. The nature of MT utilization by site managers is impacted by many factors such as data costs, inadequate network coverage, mobile device design, frequent device variant changes, and the requirement for battery recharges. The main reasons site managers choose MT are time savings and less paperwork.

2.3.5 Wearable Technologies

Wearable technologies, also known as wearable sensing devices (WSDs), are gadgets that are worn on the body. This optimizes construction processes using technology and human-technology interactions concerning construction. Examples of these gadgets are smartwatches, activity trackers, and augmented reality glasses. They track and report on a variety of health, activity, and interaction-related aspects. A growing number of sectors have WSDs to keep workers safe and healthy. Yet, Nnaji et al. (2021) observed that employees, particularly those in the construction sector, exhibit reluctance toward the utilization of WSDs because of their potential to get certain data that might be deemed confidential and personal. On construction sites, such WSDs have proven to be extremely beneficial for a variety of purposes, including workload stress and monitoring workers' fatigue (Baghdadi et al., 2019), recognizing unsafe posture in employees and potential job-related ergonomic risks (Nath et al., 2017), and minimizing injuries caused by fall and near-miss (Chan et al., 2020). There are a variety of wearable technologies available today and often utilized by construction employees, such as body sensors, smart clothes, clips, smart watches, bands, fitness trackers, smart boots, tags, and other wearable technologies (Nnaji et al., 2020). Ibrahim et al. (2024) examined wearable technology awareness and adoption for health and safety (H&S) management in Lagos State and Abuja. They found that while professionals in the construction sector are somewhat aware of common H&S wearable devices, organizations rarely use them for H&S management.

2.3.6 Big Data Analytics and Artificial Intelligence (AI)

Artificial Intelligence (AI) is an aspect of computer science concerned with developing systems that are capable of learning, thinking, solving problems, and making decisions but require human intelligence. Construction enterprises leverage AI and big data analytics to enhance decision-making processes, forecast risks, manage resources effectively, and optimize scheduling. According to Hermawati and Lawson (2019), an organization may leverage these tools to gain detailed and valuable information, giving them a competitive advantage. It is in this regard that Osunsanmi et al. (2020) opine that big data aids in the construction industry's readiness and forecasting of anticipated site conditions. Meanwhile, Kumar et al. (2020) noted that the utilization of big data analytics fosters ethical sustainability in operations and improves product traceability by integrating circular economy concepts. According to Osuizugbo and Alabi (2021), construction organizations in Lagos and Ogun States have low levels of knowledge regarding the use of AI technology in construction operations. The low awareness of the technology suggests low deployment.

2.3.7 Internet of Things (IoT)

Internet of Things (IoT) describes a network of wireless devices that are integrated with software, sensors, and other technologies. These devices exchange and gather data via the Internet, allowing for the automation and remote operation of different appliances and systems. Construction firms and sites are now able to track people, materials, and equipment in real-time as a result of the IoT, which improves resource management, safety, and productivity. Ibrahim et al. (2021) reckoned that the IoT, which is dominating our daily environment and its objects, will enable people and devices to connect anywhere, at any time, and with anyone and everything. Forcael et al. (2020) add that the IoT is revolutionizing how individuals interact with their homes not only during the building and planning stages but also during their whole lives. Some of the examples and functions of IoT technologies according to Dilakshan et al. (2021) include wearables and gadgets used to track daily work activities, monitor heart rate, forecast circadian rhythm, automatically sound an alarm if people fall asleep, and notify users in the event of an intruder in private areas. Khurshid et al. (2023) noted that the construction industry has been slow in adopting IoT technology compared to other industries. Despite the rapid growth of the construction industry driven by urbanization and population increase, it remains one of the least digitized sectors with minimal integration of IoT and artificial intelligence. Construction sites are gradually being turned into smart working environments as IoT sensors and other digital technology become more prevalent (Abioye et al., 2021). Oke and Arowoiya (2021) revealed that the construction sector in Lagos State mostly uses IoT in the areas of building information modeling, construction management, remote usage monitoring, equipment maintenance and repair, construction tools, and equipment tracking. Besides, Oke et al. (2022) add that the adoption of IoT has a significant impact on construction workers' productivity, safety, privacy, and security.

2.3.8 Digital Twin (DT)

Digital Twin (DT) is a virtual version of a real-world system, process, or item that is used to replicate, evaluate, and track its counterpart in real time. This allows for better decision-making and predictive insights. A construction organization employs DT technologies during the building phase to simulate and optimize operations, improve coordination, and track progress in real time. Ajayi et al. (2022) and Rahman et al. (2022) note that DT technologies integrate artificial intelligence (AI), machine learning (ML), and data analytics. It does this by utilizing data from real-world IoT sensors to feed models into AI, ML, and/or statistical software, which then generates meaningful findings and judgments. DTs prioritize data transmission and models between digital models and actual things (Akanmu et al., 2021). DTs might be useful for a variety of tasks, including data collection, device monitoring, and future planning (Javaid et al., 2022). The application of DTs on building projects in Lagos State is currently evolving. While large construction firms and projects may be experimenting with or deploying such technology for project, planning, management, monitoring, and control, its mainstream use by CMSMEs remains restricted. The adoption of digital twin (DT) technology to improve the sustainability of construction projects, worker safety, and project performance is a widespread practice in industrialized nations (Arowoiya et al., 2024). Incorporating DTs might help developing nations like Nigeria, particularly Lagos State, to drive project outcomes.

2.3.9 Robotics and Automation Technologies

Autonomous robots are devices that can carry out activities and make choices without the need for human input. They can navigate and function autonomously in a variety of situations by utilizing sensors, artificial intelligence, and algorithms. In recent times, construction companies have started using autonomous robots to carry out certain tasks on their projects. Among the tasks performed to improve accuracy and efficiency during the building production phase include bricklaying, concrete placement, and site inspection. For instance, a commercial brick-laying robot that can build a whole house in two days was demonstrated (Oesterreich & Teuteberg, 2016). Some robots transport building materials to job sites, screed floors, render walls, and lay asphalt and road courses, among other tasks (Lekan et al., 2020). Balasubramanian et al. (2021) claim that using autonomous robots can improve production efficiency and quality while reducing human error and production completion times. According to Suleiman et al. (2022), autonomous robots are intelligent machines that can perform certain activities with minimal assistance from humans. Additionally, Kumar et al. (2020) opine that Autonomous robots are suitable for industrial applications in hazardous situations; their use also increases the flexibility, ethics, and sustainability of production processes. Oke et al. (2023) revealed that the Nigerian construction industry exhibits a significant lack of implementation of automation techniques, which raises concerns. Although the opportunities for adopting robotics in the construction industry include increased productivity, increased speed, reduced workload on operators, and improved safety (Amaifeobu et al., 2023). According to Oluseye et al. (2022), the belief that the construction industry employs a large number of people is the biggest barrier to the adoption of robotics and automation technologies in Lagos state. The study concluded that those who use RACS do so mostly because it makes their jobs more efficient. In addition, the majority of heavy construction contractors in Nigeria are multinational firms. This, along with the projects' large profit margins or high cost may have contributed to their ability to use this equipment. This shows that the Nigerian construction sector is not yet technologically developed enough to use fully automated machinery for building tasks.

2.3.10 Additive Manufacturing/ 3D Printing

Additive manufacturing (AM), also referred to as 3D printing, is the technique of making items by layering on material based on digital models. This method produces the least amount of trash while enabling intricate patterns and customization. Construction firms utilize AM technology to create building components on-site, which saves time and material waste while improving personalization and flexibility of design. Shahzad et al. (2022) described AM as a technique that builds a 3-D object from a computer-aided design model using layers of material. To put it another way, products are designed digitally and produced by layering on the material (Hernandez-de-Menendez et al., 2020), which greatly expands the possibilities for mass customization (Zheng et al., 2021). Meanwhile, Shahzad et al. (2022) revealed that this innovative approach to building improves on conventional techniques by addressing difficulties such as less dependence on human resources, cheaper investment costs, and the removal of formworks. Opawole et al. (2022) opined that there is a low level of awareness and implementation of additive manufacturing in Lagos state. The study found that there is still a lack of awareness and application of the technology, as the majority of the firms in the study (80.8%) learned about the technology through professional discussions and personal research, rather than through using it in their daily operations. The low level of adoption was attributed to concerns about cost, complexity, and limited access to necessary resources could deter professionals from adopting this technology.

2.3.11 Building Information Modelling (BIM)

An infrastructure project's or building's functional and physical attributes can be digitally represented using BIM. It facilitates planning, design, building, and operations by combining 3-dimensional (3D) modeling with data management. To enhance efficiency and accuracy during the building production phase of a project, construction firms employ BIM for real-time collaboration, conflict detection, and construction sequencing. According to Muñoz-La Rivera et al. (2021), BIM is a collaborative process that involves developers, designers, contractors, subcontractors, and suppliers to plan, execute, and operate construction projects. To this end, the application of the various dimensions of BIM has been reported. Georgiadou (2019) states that the 3D BIM embodies shape and size, 4D BIM embodies schedule (Martínez-Aires et al., 2018; Panteli et al., 2020; Abioye et al., 2021), 5D BIM embodies cost (Alizadehsalehi & Hadavi, 2023), 6D BIM embodies sustainability, and 7D BIM embodies facilities management and as-built data (Gao et al., 2019), while the 8D BIM embodies safety (Soares-Júnior et al., 2021; Saada & Aslan, 2022). The application of BIM technologies in the Nigerian construction sector, particularly in Lagos State has witnessed a significant shift. According to Abdullah and Ibrahim (2016), BIM was developed as a framework to address the shortcomings of traditional Computer Aided Drawing (CAD) systems. It does this by providing a useful digital interface that combines a building's essential details into a digital filing system that is used by the different project stakeholders. According to Olanrewaju et al. (2020), a lot of professionals still use 2D CAD and other antiquated techniques for design and documentation, which has slowed down the adoption of BIM. Since cooperation is crucial to optimizing the advantages of BIM, the absence of integration across many disciplines during the construction process makes its application even more difficult (Onungwa & Uduma-Olugu, 2017). Social perceptions and a lack of concrete information on the financial advantages of BIM are the main obstacles preventing its implementation in Lagos State (Oladiran et al., 2023). Moshood et al. (2020) state that the early use of BIM in project inception has considerable benefits for the Nigerian construction sector. The adoption of BIM among Nigerian architects was found to be low, despite their strong familiarity with BIM-related vocabulary (Ezeji et al., 2023). Moreover, Oladiran et al. (2024) conclude that there is potential for BIM adoption in Lagos, Nigeria, however, it is likely to be limited to larger projects as small firms may not prioritize the deployment of BIM in Nigeria shortly.

2.3.12 Radio Frequency Identification (RFID)

Radio Frequency Identification (RFID) is a technique that employs radio waves to automatically identify and track things outfitted with RFID tags, which carry stored data that RFID readers can read without requiring physical touch. RFID technology is used by construction firms to track materials, machinery, and workers during project construction, therefore improving inventory management, workflow efficiency, and site security. According to Ibrahim et al. (2021), the RFID function in a construction project is linked to labor, material controls, usage of construction equipment, and maintenance of the project. RFID is typically used for access control, which keeps an eye on the number and identity of workers on construction sites and prevents illegal personnel from accessing (Oesterreich & Teuteberg, 2016). Meanwhile, You and Feng (2020) opined that RFID technologies are used to track the tags implanted in the components and get real-time data during the construction-site assembly process. Mabad et al. (2021) highlights low adoption of RFID technologies in the construction industry. Kineber et al. (2023) found that Nigeria, like many other developing countries, faces challenges in using RFID for sustainable building and large-scale projects. This has highlighted the necessity for RFID deployment to help ameliorate the issue. This study found that RFID is a long-term strategy to combat that threat. In contrast, the use of RFID technology by building enterprises in the most noteworthy developing nations, such as Nigeria, remains low.

3.0 RESEARCH METHOD

The study area is Lagos State, Nigeria. Lagos State was selected for the study because of the concentration of construction firms utilizing various innovative technologies to enhance their day-to-day operations and management of building sites. The State is often regarded as the epicenter of Nigerian building activity, accounting for a sizable proportion of the country's developments. There are 20 Local Government Areas in Lagos state. Meanwhile, there are 16 local government areas in Lagos Metropolis. They include Agege, Ajeromi/Ifelodun, Alimosho, Amuwo Odofin, Apapa, Eti-Osa, Ifako/Ijaye, Ikeja, Kosofe, Lagos 47 Island, Lagos Mainland, Mushin, Ojo, Oshodi/Isolo, Shomolu, and Surulere. According to Simeon and Soyingbe (2023), the state has the largest concentration of construction micro-small-medium organizations involved in the construction of buildings. According to Simeon et al. (2024), Lagos State is a significant urban center with a complex interplay between population dynamics and building procurement activities. It is the most populated Metropolis in Nigeria with over 24 million inhabitants, making it the second-largest city in Africa after Cairo. Lagos is a significant African financial center as well as the economic center of Nigeria. The survey covered major urban centers in Lagos Metropolis including the Lagos Mainland and Lagos Island, areas known with a high number of building and infrastructural works and where innovative technologies are usually deployed among organizations.

The population under investigation comprised construction professionals employed by micro, small, and medium enterprises. The targeted respondents were professionals who utilized some level of construction technologies during the construction phase of projects. The study adopted a survey research strategy to collect data from the targeted respondents who were construction managers, project managers, quantity surveyors/estimators, site engineers, and site managers. The viewpoints of these targeted experts were required since they are the major stakeholders involved in the building production phase. Umeh (2018) defines a research population as all subjects, elements, or observations related to a specific phenomenon that share a common feature or characteristic. The researcher used a non-probability sample approach since there was no database of registered construction micro, small, and medium enterprises (CMSMEs) at the time of the study. A sample size of 97 was drawn based on the rule of thumb theory. According to Roscoe (1975), the ideal sample size for a study is between 30 and 500 participants. A total of 154 questionnaires were distributed, with 109 completed and returned, indicating a 70.8% response rate. Criterion based; deliberate, purposive sampling research strategy was used to select 109 respondents from the population. Purposive sampling is a non-probability sampling strategy that must have explicit inclusion criteria and justification. Obilor (2023) corroborates that purposive sampling chooses sample participants based on established criteria and the researcher's experience and knowledge. A close-ended questionnaire was designed to collect data from the targeted respondents who work in CMSMEs. The large-scale construction enterprises were excluded from this study because they are considered established contractors and possess the capacity to deploy innovative technologies to enhance their building production processes.

The study's questionnaire was divided into 4 sections. Section A sought information on the respondents' profiles and firms' characteristics. Section B identified the socio-economic benefits of adopting technologies in the building production phase using a Likert scale of 1-4. 1 indicates strongly disagree, 2 indicates disagree, 3 indicates agree, and 4 indicates strongly agree. Section C of the research instrument evaluates the level of satisfaction on organization's deployment of innovative technologies during the building production phase on a 5-point scale where 1 connotes very dissatisfied; 2 connotes dissatisfied; 3 connotes moderately satisfied; 4 connotes satisfied; and 5 connotes very satisfied. Section D determined the degree of implementation of construction technologies during the building production phase using a Likert scale of 1-5. The scale with a notation of 1 indicates never utilized, 2 indicates rarely utilized, 3 indicates sometimes utilized, 4 indicates often utilized, and 5 indicates always utilized. A total of 154 numbers of questionnaires were self-administered to the targeted respondents on a one-off basis. At the end of the survey period of 9 weeks, 109 (70.8%) completed questionnaires were deemed valid for inclusion in the analysis. Statistical tools such as frequency counts, percentages, mean scores, relative implementation index, and ranking were used for the descriptive results. A combination of Microsoft Excel and Statistical Packages for Social Sciences (V23) was used to aid the analysis of the data. Furthermore, the reliability analysis was performed on sections B and D of the questionnaire instrument. The Cronbach's Alpha values for both sections B and D obtained were 0.873 and 0.982 respectively. These results indicate that the data collection instrument utilized for the study was consistent.

4.0 RESULTS AND DISCUSSION

This section of the study presents the results and discusses the findings.

4.1 Demographic Profile of the Participants

Table 1 reveals the demographic profile of the participants; and has been categorized into six groups. These include professional background, occupation, academic qualification, years of experience, organization size, and organization type. The highest number of participants have a background in Architecture (29.4), whilst the Quantity surveyors constitute the lowest percentage (15.6%). Table 1 also shows that 332.1% of the respondents are project managers, while 11.9% of the participants are site managers. Furthermore, a vast majority of the respondents are qualified with a Bachelor's degree (51.4%), whilst the lowest number of the participants possess a master's degree (22%). In terms of years of experience, 49.5% of the respondents have years of experience between 1 to 10 years, whilst 50.5% of the participants have over 10 years of experience in the construction industry. A majority (40.4%) of the participants work in small-sized organizations, whilst the least number of participants (29.4%) work in micro-sized organizations. These results show that the participants are very qualified and the information supplied by them may be relied upon.

Table 1. Demographic Information

Profession background	Frequency (N)	Percentage (%)
Architecture	32	29.4
Building	31	28.4
Civil engineering	29	26.6
Quantity Surveying	17	15.6
Total	109	100.0
Occupation		
Construction manager	25	22.9
Project manager	35	32.1
Quantity surveyor	17	15.6
Site engineer	19	17.4
Site Manager	13	11.9
Total	109	100.0
Academic qualification		
Higher national diploma	29	26.6
Bachelor's degree	56	51.4
Master's degree	24	22.0
Total	109	100.0
Years of experience		
1-5	19	17.4
6-10	35	32.1
11-15	31	28.4
16-20	24	22.0
Total	109	100.0
Organization size		
Small-sized with 11-50 employees	44	40.4
Medium-sized with 51-249 employees	33	30.3
Micro-sized with 1-10 employees	32	29.4
Total	109	100.0

4.2 Socio-Economic Benefits of Adopting Technologies During the Building Production Phase

Table 2 reveals the socio-economic benefits of adopting technologies during the building production phase. The objective of the study was to identify the socio-economic benefits of adopting technologies in the building production phase. To accomplish this objective, the study adopted 17 socio-economic benefits which were simplified for use from the literature review. The key construction stakeholders were asked to rate their agreement on each socio-economic benefit of adopting technologies on a Likert scale of 1-4. With 1 representing strongly disagree. A scale of 2 represents disagreement. Meanwhile, 3 represents agree, while 4 represents strongly agree. The results of the analysis are shown in Table 2. The decision rule for interpreting the relative agreement index (RAI) was adapted and modified from (Simeon et al., 2023) using the scale: 0.76 and above implies high level, 0.67-0.75 implies moderate level, 0.45 - 0.66 low level, 0.44 and below implies nil level. As seen from Table 2, these benefits have RAIs between 0.76 (increased profitability) and 0.95 (increased productivity). Table 2 shows that 17 out of the 17 advocated benefits comprising (100 percent) fell within the “high level” range. The inference to be drawn is that the construction professionals acknowledged and perceived the adoption of innovative construction technologies as highly beneficial to construction organizations. The study affirms that there are seventeen (17) socio-economic benefits construction organizations derive when innovative technologies are adopted during the building phase.

The highest ranked in the first positions are increased productivity and reduction in material wastage (RAI = 0.95) respectively. Improved worker safety (RAI = 0.90) was ranked third; the next ranked socio-economic benefits that are both ranked in fourth position are improved firms’ reputation and ease of construction (RAIs = 0.84). This is followed by improved quality (RAI = 0.833). Meanwhile, firms’ competitive advantage and efficient cost control (RAIs = 0.81) were both ranked eighth. To this end, improved return on investment and reduced risk level (RAI = 0.79) were jointly ranked tenth. Furthermore, improved communication, reduction in the cost of construction, and reduction in materials cost (RAIs = 0.77) were ranked twelfth. Moreover, the reduction in labour cost, reduced environmental impact, and increased profitability were jointly ranked fifteenth with RAIs of 0.76 respectively. These results showed that despite indicating a high level of agreement on the socio-economic benefits of adopting innovative technologies during the building production phase, several building firms are hesitant to incorporate innovative technologies owing to cost concerns, a lack of experience, fear of disruption, and a reluctance to change within conventional frameworks.

Table 2. Socio-Economic Benefits of Adopting Innovative Technologies in Construction

Socio-Economic benefits	Frequency (N)				Mean	SD	RAI	R	Remark
	1	2	3	4					
Increased productivity	0	26	80	3	3.79	0.473	0.95	1	HL
Reduction in material wastage	0	27	80	2	3.78	0.478	0.95	1	HL
Improved worker safety	0	45	65	3	3.61	0.543	0.90	3	HL
Improved firm’s reputation	0	74	32	3	3.35	0.534	0.84	4	HL
Ease of construction	0	74	35	1	3.35	0.534	0.84	4	HL
Improved quality	0	76	30	3	3.33	0.528	0.83	6	HL
Reduction in project delivery time	0	83	23	0	3.27	0.503	0.82	7	HL
Firms’ competitive advantage	0	84	21	2	3.25	0.494	0.81	8	HL
Efficient cost control	0	83	26	0	3.24	0.428	0.81	8	HL
Improved return on investment	6	79	24	0	3.17	0.500	0.79	10	HL
Reduced risk level	0	97	9	3	3.14	0.419	0.79	10	HL
Improved communication	0	103	3	3	3.08	0.363	0.77	12	HL
Reduction in the cost of construction	0	100	9	0	3.08	0.277	0.77	12	HL
Reduction in materials cost	0	106	0	3	3.06	0.329	0.77	12	HL
Reduction in labour cost	21	62	26	0	3.05	0.658	0.76	15	HL
Reduced environmental impact	0	106	3	0	3.03	0.164	0.76	15	HL
Increased profitability	21	64	24	0	3.03	0.645	0.76	15	HL

Note: 1 represents Strongly disagree, 2 represents Disagree, 3 represents Agree, 4 represents Strongly agree, HL is high level.

4.3 Satisfaction with Organization's Deployment of Innovative Technologies

Table 3 reveals the participants' degree of satisfaction with their firm's deployment of innovative technologies during the building production phase by construction firms. It follows that 58.7% of the respondents were very dissatisfied with their firm's degree of deployment of innovative technologies, 22.0% of the participants were dissatisfied with their firm's degree of deployment of innovative technologies, and 19.3% were moderately satisfied with their firms' deployment of innovative technologies. The result further revealed that none of the respondents were satisfied and very satisfied with their firms' degree of innovative technologies adoption. Similarly, none of the participants were very satisfied with the firm's degree of technology adoption. Moreover, the calculated mean score value as indicated in Table 3 was 1.61. The low mean score value indicates that the participants are dissatisfied with their organization's satisfaction with the degree of deployment of innovative technologies during the building production phase. The participants' dissatisfaction with their organizations' low level of deploying innovative technologies in construction could be attributed to the fact that it hinders safety measures, delays operations, restricts communication and lowers overall productivity.

Table 3. Level of Satisfaction with Organization's Deployment of Innovative Technologies

Type	Response rate (%)					SD	MS
	1	2	3	4	5		
Satisfaction levels	58.7	22.0	19.3	0	0	.794	1.61

Note: 1 represents Very Dissatisfied; 2 represents Dissatisfied; 3 represents Moderately Satisfied; 4 represents Satisfied; 5 represents Very Satisfied; SD represents Standard Deviation; MS= Mean Score.

4.4 Level of Adoption of Innovative Technologies by Building Firms During Building Production Phase

The study identified forty-nine (49) construction technologies that are frequently utilized by building firms in the Lagos Metropolis and categorized them into twelve (12) groups. This includes IOT; AR/VR; Laser scanners and 3D imaging systems; UAVs; Big data, AI, and machine learning; RFID; BIM; Digital twins; Mobile technology; 3D printing/additive manufacturing; Robotics and automation technologies; and Wearable technologies. In assessing the frequently adopted innovative construction technologies, the key construction stakeholders were requested to indicate their level of implementation of each construction technology using a 5-point rating scale. Where 1 indicates Never utilised; 2 indicates Rarely utilised; 3 indicates Sometimes utilised; 4 indicates Often utilised; and 5 indicates Always utilised. The results of the analysis are presented in Table 4.

Table 4 shows the computed mean values for the adoption of technologies by building firms during the construction phase. The decision rule to quantify the mean scores of the deployed practices of each technology was adapted and modified from (Simeon et al., 2023) using the scale: $1.00 \leq MS < 1.5$ symbolizes 'not deployed (ND)', $1.50 \leq MS < 2.50$ symbolizes 'rarely deployed (RD)', $2.50 \leq MS < 3.50$ symbolizes 'moderately deployed (MD)', $3.50 \leq MS < 4.50$ symbolizes 'often deployed (OD)', and $4.50 \leq MS \leq 5.00$ symbolizes 'most often deployed (MOD)'. Table 4 shows the following.

Regarding the IoT technologies, equipment and asset monitoring (2.87), construction site connectivity (2.62), and safety monitoring and emergency response (2.36) are MD practices and functionalities under the IoT category. Whereas, environmental monitoring (2.06) is an RD of the IoT technology on construction sites in the Lagos Metropolis. Regarding the AR/VR technologies, marketing and client engagement (2.60) are MD practices in the AR/VR technologies. Whereas, the practice of remote collaboration and communication (2.14), safety training and risk assessment (2.08), and on-site assistance and maintenance (1.94) of AR/VR technologies are RD during the construction stage. In respect of Laser scanners and 3D imaging systems, all the practices under this category of Laser scanners and 3D imaging systems are RD. Progress monitoring and reporting (1.79) was ranked first among the other four functionalities in this category. Concerning the UAV technologies, the practice of construction progress and monitoring (3.51) is the topmost application of the UAV technology and it is OD by construction firms during the construction phase. Other practices of the UAV technologies include inspection and asset management (3.08), surveying and mapping (3.06), and safety and risk management (2.57) all of which are MD. In respect of the big data, AI, and ML technologies, the practices of this technology include quality control and defect detection (1.68), cost estimation, and productivity optimization (1.51) respectively. In the building production stage, all three of the processes that fall under this technological category are RD. With respect to RFID technologies, all of the five functions and practices in this group are RD. Material and equipment tracking (1.95), worker tracking and safety (1.90), tools and equipment check-in/check-out (1.71), site access control, and supply chain and logistics management (1.57) are jointly tied respectively. In respect of BIM technologies, three out of the four functionalities under this category are MD. They include quantity take-off and estimating (2.83), construction safety (2.82), and construction planning and scheduling (2.62). With respect to DT technologies, all of the three functionalities under the DT group are RD. The practices include construction simulation and planning, design and visualization, and site logistics and safety planning all having mean scores of 1.51 respectively. In terms of mobile and cloud technologies, access to project information (3.76) is OD in this category of technologies and the overall highest-ranked functionality among the forty-nine enlisted practices. The functionalities of digital documentation and reporting, and time and attendance tracking are MD with mean scores of 3.33 respectively. With reference to the 3D Printing and Additive Manufacturing technologies, all of the three functionalities of this technology are ND during the construction phase. They include construction in a challenging environment, rapid fabrication of building components, waste reduction, and sustainability. They are jointly tied with mean scores of 1.39 respectively. With respect to Robotics and Automation technologies, autonomous construction (2.33), onsite assembly (1.84), and material handling and logistics (1.54) are RD by the building firms surveyed. Meanwhile, the practice of adopting a bricklaying robot (1.00) to carry out activities during the construction stage is ND. In respect of wearable technologies, the practice of using smart gloves (1.60) is RD during the building production phase. Meanwhile, the remaining six out of the seven functionalities under this category of wearable technologies are ND. It includes the practice of using smart safety vests (1.22), head-mounted displays (1.22), an exoskeleton (1.19), augmented reality sensors (1.19), RFID wristbands (1.00), and GPS tracking devices (1.00).

Table 4. Level of Technology Adoption During Building Production Phase

Technologies	Frequency					N	Mean	GR	OR
	1	2	3	4	5				
Internet of Things (IoT)							2.48		
Equipment and asset monitoring	0	23	80	3	3	109	2.87	1	7
Construction site connectivity	0	44	62	3	0	109	2.62	2	10
Safety monitoring and emergency response	0	76	27	6	0	109	2.36	3	14
Environmental monitoring	23	59	24	3	0	109	2.06	4	19
Augmented reality (AR)/Virtual Reality (VR)							2.19		
Marketing and client engagement	44	9	3	0	53	109	2.60	1	10
Remote collaboration and communication	44	6	59	0	0	109	2.14	2	17
Safety training and risk assessment	44	12	53	0	0	109	2.08	3	18
On-site assistance and maintenance	44	27	38	0	0	109	1.94	4	20
Laser Scanners and 3D Imaging Systems							1.63		
Progress monitoring and reporting	44	44	21	0	0	109	1.79	1	24
Construction documentation	50	38	21	0	0	109	1.73	2	25
Prefabrication and modular construction	44	65	0	0	0	109	1.60	3	28
Site analysis and topographic surveys	53	56	0	0	0	109	1.51	4	33
Quality Control and Inspection	53	56	0	0	0	109	1.51	4	33
Unmanned Aerial Vehicles (Drones)							3.06		
Construction progress monitoring	0	0	53	56	0	109	3.51	1	2
Inspection and asset management	0	23	54	32	0	109	3.08	2	5
Surveying and Mapping	0	0	106	0	3	109	3.06	3	6
Safety and risk management	0	47	62	0	0	109	2.57	4	13
Big Data, Artificial Intelligence and Machine Learning							1.57		
Quality control and defect detection	56	32	21	0	0	109	1.68	1	26
Cost estimation	53	56	0	0	0	109	1.51	2	33
Productivity optimization	53	56	0	0	0	109	1.51	3	33
Radio Frequency Identification (RFID)							1.74		

Material and equipment tracking	47	41	0	21	0	109	1.95	1	20
Worker tracking and safety	53	35	0	21	0	109	1.90	2	22
Tools and equipment check-in/check-out	53	35	21	0	0	109	1.71	3	26
Site access control	47	62	0	0	0	109	1.57	4	30
Supply chain and logistics management	47	62	0	0	0	109	1.57	4	30
Building Information Modelling (BIM)							2.63		
Quantity take-off and estimation (5D)	0	21	85	3	0	109	2.83	1	8
Construction safety (8D)	0	23	83	3	0	109	2.82	2	9
Construction planning and scheduling (4D)	0	44	62	3	0	109	2.62	3	10
Sustainable materials (6D)	0	85	21	3	0	109	2.25	4	16
Digital Twin							1.51		
Construction simulation and planning	53	56	0	0	0	109	1.51	1	33
Design and visualization	53	56	0	0	0	109	1.51	1	33
Site logistics and safety planning	53	56	0	0	0	109	1.51	1	33
Mobile Technology							3.47		
Access to project information	0	0	29	77	3	109	3.76	1	1
Digital documentation and reporting	0	0	76	30	3	109	3.33	2	3
Time and attendance tracking	0	0	76	30	3	109	3.33	2	3
3D Printing and Additive Manufacturing							1.39		
Construction in a challenging environment	88	0	21	0	0	109	1.39	1	40
Cost and time efficiency	88	0	21	0	0	109	1.39	1	40
Waste reduction and sustainability	88	0	21	0	0	109	1.39	1	40
Robotics and Automation Technologies							1.67		
Autonomous construction	23	27	59	0	0	109	2.33	1	14
Onsite assembly	23	80	6	0	0	109	1.84	2	23
Material handling and logistics	50	59	0	0	0	109	1.54	3	30
Bricklaying robot	109	0	0	0	0	109	1.00	4	47
Wearable Technologies							1.20		
Smart gloves	47	59	3	0	0	109	1.60	1	28
Smart safety vest	85	24	0	0	0	109	1.22	2	43
Head-mounted display	85	24	0	0	0	109	1.22	2	43
Exoskeleton	88	21	0	0	0	109	1.19	4	45
Augmented reality sensor	88	21	0	0	0	109	1.19	4	45
RFID wristband	109	0	0	0	0	109	1.00	6	47
GPS tracking devices	109	0	0	0	0	109	1.00	7	47

Note: 1 indicates Never utilized; 2 indicates Rarely utilized; 3 indicates Sometimes utilized; 4 indicates Often utilized; 5 indicates Always utilized; N indicates Total number of respondents; GR indicates Group Ranking, OR indicates Overall Ranking.

4.5 Discussion of Findings

The findings showed that there is a generally low deployment rate of the IoT technology (2.48). The challenges that hinder the widespread deployment of IoT technologies during the construction phase could be attributed to the high cost of implementing IoT solutions and the complexity of IoT systems. This result aligns with the assertions of Khurshid et al. (2023) that the construction sector has been hesitant to deploy IoT technologies compared to other industries. Contrarily, Oke et al. (2022) note that the adoption of IoT has a significant impact on construction workers' productivity, safety, privacy, and security. This implies that construction firms that use IoT will gain an edge over competitors by lowering costs, mitigating risks, boosting efficiency, and making informed choices to improve project results. Besides, the findings revealed that the overall deployment of the AR/VR technologies (2.19). The low level of deployment could be attributed to the likelihood that many professionals in the construction industry are not completely cognizant of the potential benefits and capabilities of these technologies. This finding conformed to the claims of Ikuabe et al. (2020) that there is a low level of adoption of AR/VR technologies on construction projects. To this end, the overall level of deployment of the Laser scanners and 3D imaging system technologies is low. Construction firms that deploy laser scanners experience greater productivity, cost savings, enhanced project quality, and improved stakeholder communication via accurate, real-time data and better site monitoring. Further questioning revealed that workflows and techniques used in construction may need to be significantly altered to incorporate laser scanners and 3D imaging features. There is a moderate level of deployment of the UAV technologies (3.06). The moderate deployment of UAV technologies is a result of their ability to offer real-time data, project tracking, and safety oversight during the building production phase. This finding aligned with the assertions of Alzarrad et al. (2022) and Molina et al. (2023) that UAVs can effectively monitor infrastructures in addition to providing other benefits. Taibat et al. (2023) accentuated the discovery of this study that there is a low level of deployment of UAVs among building project sites in Lagos State. The reason adduced for the modest deployment rate according to Yahya et al. (2019) included the exorbitant cost of acquisition and the cost of maintaining and updating the technologies. Nonetheless, construction firms that use UAVs gain a competitive edge by increasing efficiency, lowering operation hazards, improving accuracy, and lowering project costs thereby resulting in total industry innovation. About big data, AI, and ML technologies, there is an overall low level of adoption of technologies during the building production phase. The reasons for the non-deployment of these practices from further questioning of the respondents are attributed to the insufficient resources to develop, adopt, and maintain the technologies effectively. Osuizugbo and Alabi (2021) validated this finding that construction organizations in Lagos and Ogun States have low levels of knowledge regarding the use of AI technology in construction operations. This finding implies that organizations that deploy AI are most often going to experience better project management, fewer delays, more safety, greater cost efficiency, and information-driven choices, all of which contribute to more successful on-time construction outputs. In respect of RFID technologies, there is a low adoption rate (1.74) of the technologies. The low deployment of RFID technologies during the building production phase could be because SMEs find it challenging to locate RFID technology providers who understand their unique requirements and give enough assistance and guidance during the deployment process. The results align with the research conducted by Mabad et al. (2021), which emphasize the limited uptake of RFID technology in the construction sector. Kineber et al. (2023) corroborate this finding that Nigeria, like many other developing countries, faces challenges in using RFID for sustainable building and large-scale projects. Meanwhile, organizations that deploy RFID technology improve inventory monitoring, increase asset visibility, reduce theft, streamline logistics, and ensure improved project management and utilization of resources. There is a moderate (2.63) overall level of deployment of BIM technologies during the building production phase. The moderate deployment of the BIM technologies during the building process could be attributed to the diverse benefits it offers as presented by Georgiadou (2019) that the 3D BIM embodies shape and size, 4D BIM embodies schedule (Martínez-Aires et al., 2018; Panteli et al., 2020; Abioye et al., 2021), 5D BIM embodies cost (Francisco, 2023; Alizadehsalehi & Hadavi, 2023). Meanwhile, previous studies by Oladiran et al. (2024) on BIM adoption in Lagos state validated the findings of this study on the minimal deployment of BIM among CMSMEs, indicating that BIM has a promising future only among large construction enterprises. When BIM is deployed, construction firms operate more effectively by reducing costly mistakes, improving cooperation, and making informed decisions, resulting in better project outcomes and profitability. There is an overall low level of deployment of DTs (1.51) during the construction phase. The underutilization of the DT functionalities may be due to complex project structures, unwillingness to deploy emerging technologies, and the lack of standardization. This is consistent with research by Turner et al. (2021) that shows the construction sector still has difficulties implementing DTs. This indicates that construction companies may cut expenses, improve project accuracy, increase efficiency, and make better judgments, resulting in higher-quality, and more successful projects when DTs are employed. The mobile and cloud technologies obtained the highest overall mean score of 3.47 among all the twelve innovative technologies deployed during the construction stage of building projects. The technology's high adoption rate could result from its usefulness in today's fast-paced construction industry as these technologies' mobility gives project managers more freedom and makes it possible for teams to operate productively from any location. Marzano and Martinovs (2020) opined that mobile or cloud technologies involve a process of organizing, processing, and storing data on interconnected, remote servers located on the Internet. Olugboyega et al. (2022) add that site managers in Lagos state view mobile technology (MT) as a personal property and that their main usage of it has been for social and private purposes. It suggests that construction firms may increase productivity, complete projects faster, and enhance safety by making good use of mobile equipment and technology on-site. The 3D printing technology or additive manufacturing technologies are not deployed (1.39) during the construction phase in Lagos Metropolis. The reason adduced is that CMSMEs frequently operate on smaller projects where conventional building methods are more economical and efficient. In this sense, CMSMEs might choose to invest in technology and practices with an extra immediate and tangible influence on their firm. Moreover, the market for 3D-printed building solutions may remain restricted or specialized, particularly in specific geographic locations or sectors. The non-deployment of additive technologies during the construction phase conformed to the findings of Opawole et al. (2022) that there is a very low level of use of 3D printing technology for building housing delivery in Lagos Metropolis. The low level of adoption was attributed to concerns about cost, complexity, and limited access to necessary resources could deter professionals from adopting this technology. Construction firms that employ additive manufacturing increase design flexibility, improve sustainability, and optimize workflows by reducing costs and boosting efficiency, with the potential to significantly transform the construction sector by expanding. Construction organizations are hesitant to deploy robotics and automation technologies (1.67) because it is sometimes too expensive for many construction enterprises, especially smaller ones, to use robots and automation in the construction industry since it frequently involves substantial initial investments in technologies, machinery, and infrastructure. This supports the findings of Oke et al. (2023), which showed that there is a concerning absence of automation technology applications in the Nigerian construction industry. Yet, there are still prospects for robotics adoption in the construction sector, including higher productivity, faster operations, less human workload, and enhanced safety (Oluseye et al., 2022; Amaifeobu et al., 2023). This indicates that construction firms that employ autonomous robots for their day-to-day construction works will increase productivity, reduce costs, promote and enjoy safer practices while positioning firms for sustainable growth and development. The wearable technologies were not deployed (1.20) among any of the building sites surveyed. Construction firms' reluctance to deploy wearable sensing devices is influenced by worries about their durability and safety in the demanding construction industry, as well as the security of information and privacy risks associated with the gathering and sharing of worker data. Nnaji et al. (2021) buttressed the result of this study that employees, particularly those in the construction sector, exhibit reluctance toward the utilization of wearable sensing devices because of their potential to get certain data that might be deemed confidential and personal. Moreover, Ibrahim et al. (2024) buttressed the findings of this study by examining wearable technology awareness and adoption for health and safety (H&S) management in Lagos State and Abuja and found that while professionals in the construction sector are somewhat aware of common H&S wearable devices, organizations rarely use them for H&S management. To this end, construction firms that deploy wearable sensing devices enhance productivity and industry standards by lowering workplace injuries, encouraging proactive decision-making, and tracking safety and health in real-time. Meanwhile, the socio-economic benefits of adopting innovative technologies during the building production phase. The findings conform to Oesterreich and Teuteberg (2016) who stated that when the technologies are completely integrated into the construction sector, the industry will gain from quicker project delivery and higher-quality projects at lower costs. Furthermore, Demirkesen and Tezel (2021) substantiate that the key benefit of technology adoption for the construction sector is its capacity to develop business models and production processes that are more efficient, as well as to improve construction value chains.

5.0 CONCLUSION AND RECOMMENDATIONS

The study uncovered seventeen benefits organizations derive when innovative technologies are deployed during the building production phase. The most significant benefits are increased productivity, reduction in material wastage, and improved project quality. This implies that building firms in the Lagos Metropolis that deploy innovative technologies during the building production phase of their projects will significantly reap the benefits accrued from the findings of the study. Additionally, the research outlined 49 technological aspects that are used during the construction production stage and grouped them into 12 categories. Their degree of deployment, however, differs across various building firms. Wearable technology is the least used among the building firms investigated, despite mobile technology being frequently used by construction organizations. This suggests that the construction companies in the metropolitan areas of Lagos are yet to leverage technological tools to enhance construction projects while buildings are being built. Moreover, the study concludes that access to project information greatly enhances decision-making, and operational efficiency in CMSMEs. Construction firms may increase teamwork, minimize errors, and expedite communication by implementing mobile applications, cloud-based platforms, and real-time data-sharing solutions. This indicates that implementing strong information access features makes CMSMEs more competitive in a quickly changing industry landscape while also improving project outcomes. In light of the conclusions, this study makes the following recommendations. Construction organizations should leverage innovative technologies to enhance the construction phase. This may be accomplished by creating a budget for its uptake and deployment during the building production phase in a bid to unlock its full potential and benefits. Moreover, manufacturers of underutilized technologies should amplify product awareness among building firms in the Lagos Metropolis. This may be achieved by organizing training and demonstration programs for construction industry stakeholders on the benefits of deploying the technologies. Besides, construction firms should invest in integrated digital systems that enable real-time access to project information to improve operational efficiency and competitiveness. This can be achieved by utilizing mobile apps, cloud-based solutions, and collaborative tools to enhance team communication. CMSMEs should also promote a transparent and accountable culture and set clear guidelines for data sharing to get the most out of innovative technologies by training staff. These systems will satisfy changing project demands if they are routinely evaluated and updated, which will eventually enhance project performance and increase industry flexibility. This may be accomplished by implementing pilot projects, providing comprehensive training to employees, as well as keeping abreast with innovative technologies to sustain firms' competitiveness.

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