Analysis of Digital Technology Adoption Benefits for the Maintenance of Higher Educational Building Facilities

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Abstract
The continued exploration and adoption of digital technologies are essential for tertiary educational institutions' future resilience and competitiveness. As tertiary institutions face the growing complexity of managing extensive physical assets, digital technologies offer indispensable tools that enhance maintenance operations' precision, effectiveness, and efficiency. This study evaluated the benefits of using digital technologies to manage higher educational building facilities in Nigeria. A post-positivist philosophical approach guided a quantitative research methodology employing a questionnaire survey for this study. The population comprised selected builders, architects, quantity surveyors, civil engineers, technicians, and artisans, who are the maintenance team involved in using digital technologies to maintain constructed facilities in the higher education sector. Using the purposive sampling technique, ninety (90) questionnaires were distributed manually and retrieved, screened, and analysed using descriptive and inferential analysis, while Cronbach's Alpha tested the reliability. The mean scores range from 3.16 to 4.33, indicating a generally positive perception among respondents regarding the benefits of digital technologies. The Kruskal-Wallis H test outcome revealed that the respondents' opinions agreed since most p-values were greater than 0.05. The study revealed the foremost benefits: enhanced decision-making, increased productivity, and improved quality in maintenance services. It is recommended that, to maximise the benefits of adopting digital technologies in maintenance activities, institutions facing challenges in technical support should consider outsourcing technical expertise to bridge knowledge gaps. Moreover, institutions must develop a robust financial plan to support acquiring and maintaining digital technologies. The study is a foundational resource for future research and practice in digital maintenance management.

Keywords
Digital technologies, Maintenance, Facilities, Drivers, Higher institutions, Nigeria.

1. Introduction
Innovative and digital technologies are paramount to efficiently maintaining higher educational building (HEB) facilities. Digital technology, in the context of maintenance management, refers to a suite of electronic tools, systems, devices, and resources that collectively facilitate the management and execution of maintenance activities within an organisation (Algabroun et al., 2022). In the realm of tertiary institutions, where the maintenance of a vast array of physical assets, from classrooms and laboratories to libraries and administrative buildings, is crucial, digital technology plays a pivotal role. The core purpose of digital technology in maintenance management is to ensure that all physical assets are kept in optimal working condition, thereby extending their lifespan and reducing downtime (Jasiulewicz-Kaczmarek & Gola, 2019). This is achieved through a variety of digital solutions. For example, Computerised Maintenance Management Systems (CMMS) offer a structured approach to scheduling, tracking, and completing maintenance tasks. These systems allow institutions to automate maintenance processes, streamline operations, provide a digital record of maintenance activities, and enhance accountability and transparency (Ismail, 2019). Moreover, the integration of Internet of Things (IoT) devices further enhances maintenance management by providing real-time data on the condition of assets. Such devices can monitor parameters like temperature, pressure, and usage, sending alerts when deviations occur, thus enabling a more proactive maintenance approach. This shift towards predictive maintenance, supported by data analytics, helps institutions pre-empt potential breakdowns and schedule repairs before failures disrupt the educational process (Lai et al., 2019). Thus, digital technology in maintenance management supports the fundamental goal of maintaining and improving physical infrastructure and introduces a level of efficiency and predictive capability that was previously unattainable. This transformative

impact underscores the importance of digital solutions in strategically managing institutional resources, leading to improved operational effectiveness and reduced overall maintenance costs (Selcuk, 2017). This indicates a need to make a case for the relevance of digital technologies in maintaining HEB facilities.

Numerous studies have underscored the importance of adopting digital technology for improving maintenance practices in tertiary institutions, highlighting its transformative impact on operational efficiency and resource management (Kumar & Galar, 2021; Jambol et al., 2024). As tertiary institutions face the growing complexity of managing extensive physical assets, digital technologies offer indispensable tools that enhance maintenance operations' precision, effectiveness, and efficiency. Bhanji et al. (2021) have shown that institutions leveraging digital solutions like Computerised Maintenance Management Systems (CMMS) and Internet of Things (IoT) devices achieve significant improvements in maintaining asset reliability and reducing unplanned downtimes. For instance, a study by Velmurugan and Dhingra (2021) revealed that the deployment of CMMS in educational institutions not only streamlined maintenance operations but also facilitated better planning and allocation of resources, leading to cost savings and enhanced asset management. Similarly, IoT devices have been documented to allow real-time monitoring of facilities, which aids in early detection of issues before they escalate into costly repairs, as discussed in the work by Iluore et al. (2020). Furthermore, the strategic integration of predictive analytics into maintenance practices further exemplifies the benefits of digital adoption. Predictive maintenance, as opposed to reactive maintenance, utilises data collected from various digital sources to predict equipment failures before they occur. This approach significantly reduces maintenance costs and increases the longevity of assets, contributing to a more sustainable operational model (Achouch et al., 2022). Chavez et al. (2022) emphasised that this data-driven maintenance strategy enhances decision-making processes and operational transparency, which are crucial for managing educational facilities. Moreover, adopting digital technologies in maintenance management aligns with broader institutional sustainability and efficiency goals. By reducing resource waste and optimising maintenance schedules, institutions save on operational costs and contribute to environmental sustainability (Ebirim et al., 2024). The enhanced data collection and analysis capabilities provided by digital tools offer deeper insights into facilities' performance and usage patterns, enabling more informed decisions that align with best sustainability practices. Additionally, past studies have supported the importance of digital technology in improving maintenance practices within tertiary institutions. These technologies enhance the operational aspects of maintenance management and align with the strategic goals of cost efficiency, sustainability, and improved service delivery. The continued exploration and adoption of these digital solutions are essential for tertiary educational institutions' future resilience and competitiveness (Etukudoh, 2024).

The issues surrounding the inadequate management of organisational maintenance activities could be overwhelming. Khalil and Husin (2011) explained that higher institutions' educational systems and learning activities are usually at risk when the buildings experience poor performance. There have been many criticisms in the media and literature that university buildings are not performing as expected due to poor management ideas; this expresses the absence of value-added services by maintenance organisations. Buys *et al*. (2009) and Zulkarnain et al. (2011) asserted that the performance of tertiary institutions in maintenance management is far below best practice. There is no doubt that there could be a problem of insufficient funds, but the foremost issue is attributed to poor management philosophy and principles. Thus, Lateef, Khamidi and Idrus (2010) noted that poor maintenance management systems have always led to preventable increases in maintenance costs, inadequate user satisfaction and low productivity. The foregoing poses questions like: What could the management of maintenance organisations in tertiary institutions do to improve their services? Are there no innovative ideas, especially in information technology, that can be inculcated for effective management of maintenance activities? The extant literature indicates an inadequate emphasis on the criticality of digital technologies for the efficient maintenance management of HEB facilities. Hence, this study aims to evaluate the benefits of adopting digital technologies for efficient maintenance management of HEB facilities in Nigeria. This is to foster the adoption of these technologies by the stakeholders and professionals in the tertiary educational sector.

2. Research Methodology

This study adopted a post-positivist philosophical approach to use empirical data to identify the benefits of implementing digital technologies to maintain HEB facilities in Nigeria. This philosophical viewpoint influenced the necessity for a quantitative research strategy employing a questionnaire survey. Creswell (2014) states that the quantitative research approach collects numerical data that may be categorised, ranked, or assessed using units of measurement. Using data from the reviewed literature, a closed-ended questionnaire was created for this study to collect data from the target population. There were two distinct portions of the questionnaire. Section A collected data regarding the respondents' backgrounds, while Section B concentrated on the perceived benefits of adopting digital technologies to maintain HEB facilities. Participants answered the questionnaires using the five-point Likert scale given in the survey to rate their agreement or disagreement with the variables; this was also adopted to boost response rate and quality. Due to the statistical approach of the research study, a target population was drawn, which included maintenance personnel in the higher educational institutions within Nigeria. The selected professionals/respondents are builders, architects, quantity surveyors, civil engineers, technicians, and artisans. These professional groups were selected as they are directly involved in maintaining constructed facilities in the higher educational sector. A purposive sampling technique was adopted to ensure that only professionals directly involved in maintaining tertiary educational facilities were used for the study. Maintenance personnel who are adequately grounded in digital technologies formed the highest percentage of respondents since they are qualified through knowledge, education, experience, and expertise in the subject matter. According to Adetayo (2001), the purposeful sampling approach is a non-probability sampling approach based on the population's characteristics and the study's objectives. According to Neuman (2006) and Aigbavboa (2014), sampling is choosing a subset from a specific population. The subgroup then serves as the study's sample (Neuman, 2006; Aigbavboa, 2014). Hence, maintenance personnel in tertiary institutions within southwest Nigeria were chosen to conduct this study purposefully. The southwestern part of the country was used for the study because of its proximity at the time; it forms part of an academic project. The entire 90 copies of the questionnaire that were administered were recovered. Every recovered questionnaire was examined and determined to be appropriate for analysis. Tables were used to derive statistical conclusions based on their responses. The Statistical Package for Social Science software (version 29) was used to evaluate the recovered replies. The respondents' demographic data were analysed using percentiles and frequencies, and the mean item score (MIS) rated the variables based on the respondents' responses. In addition to the descriptive analysis, an inferential investigation of the differences in the viewpoints of the different respondent groups on the benefits of digital technology usage in maintaining tertiary educational facilities was conducted. This was accomplished using the Kruskal-Wallis H test, which is suitable for determining the differences in respondents' opinions that belong to more than two groups (Yong & Pearce, 2013). The inferential statistic was carried out to ascertain the extent to which the stakeholders and professionals agree on the benefits of digital technologies, thereby outlining the key drivers or benefits. The reliability of the research instrument was measured using Cronbach's alpha, giving a value of 0.878. This confirmed that the data retrieved using the questionnaire survey can be relied upon.

3. Research Findings & Discussion

3.1 Demographic Information of Respondents

After completing the survey, ninety (90) responses were collected for analysis in this study. From the 90 responses, the outcome on the respondents' years of experience revealed that most of the respondents (70%, n = 63) had 6 to 10 years of experience in their respective fields, while 16.7% (n = 15) had 1 to 5 years of experience. A smaller percentage had more than 10 years of experience, with 6.7% (n = 6) having 11 to 15 years and 3.3% (n = 3) having 21 to 25 years or above 25 years. This reflected that most of the respondents had the requisite experience in working in the maintenance sector; the result of the study was considered adequate since those who had experience managing constructed facilities were administered the questionnaire. The educational qualification outcome showed that most respondents (66.7%, n = 60) held a Bachelor's degree (B.Sc.). In comparison, 26.7% (n = 24) had a Higher National Diploma (HND), and 6.7% (n = 6) had a Master's degree (M.Sc.). This educational distribution suggests that most participants possess a high academic qualification, which may correlate with their professional roles and capacity to engage with advanced digital technologies. The professional affiliation outcome revealed that 66.7%(n=60) of the respondents were affiliated with the Nigerian Institute of Quantity Surveyors (NIQS), making it the most represented professional body in the study. The Nigerian Institute of Building (NIOB) accounted for 16.7% (n = 15) of the participants, followed by the Nigerian Institute of Architects (NIA) with 6.7% (n = 6) and the Nigerian Society of Engineers (NSE) with 10% (n = 9). This indicates that the respondents of this study are not quacks but incorporated professionals in their various professional and regulatory bodies.

3.2 Benefits of Digital Technology Usage for Maintenance of HEB Facilities

Table 1 presents the perceived benefits of using digital technologies to maintain HEB facilities in Nigeria. It presents the mean scores for various variables related to the relevance of digital technologies in maintenance activities based on responses from the study participants. The mean scores range from 3.16 to 4.33, indicating a generally positive perception among respondents regarding all the benefits. Using the Kruskal-Wallis H test, Table 1 also displays the results of the differences in opinion among the respondents. Asymp. Sig. scores below 0.05 in the

Kruskal-Wallis H test suggest that respondents' opinions differ significantly. The highest-ranked benefit is "Enhanced decision-making" with a mean score of 4.33, indicating that digital technologies are perceived to improve decision-making processes in maintenance management significantly. Similarly, increased productivity (M = 4.23, ranked 2nd) and improved efficiency (M = 4.03, ranked 6th) are other significant benefits of using digital technologies, underscoring the positive impact on operational performance. Furthermore, "improved communication and collaboration among stakeholders" (M = 3.93, ranked 13th) is recognised as a benefit for institutions, while "increased transparency and accountability" (M = 3.20) was ranked 20th. The relatively lower ranking of benefits such as "enhanced predictive maintenance capabilities" (M = 3.40, ranked 18th) and "increased use of analytics for data-driven decisions" (M = 3.16, ranked 21st) suggests that more sophisticated digital maintenance technologies may not yet be fully utilised in these institutions. Hence, there may be low knowledge of the significance of such advanced technologies.

Table 1. Perceived benefits associated with using digital technologies for maintenance

Benefits	Mean	Kruskal-Wallis H	Asymp. Sig.	Rank
Enhanced decision-making	4.333	3.4784	0.6267	1
Increased productivity	4.233	22.1464	0.0005	2
Improved quality of maintenance services	4.133	4.7084	0.4525	3
Improved ability to identify and address potential issues before they become major problems	4.133	4.7791	0.4434	3
Improved safety and risk management	4.067	3.4407	0.6324	5
Improved efficiency	4.033	4.2572	0.5130	6
Reduced downtime and improved uptime	4.000	4.4096	0.4921	7
Improved compliance with regulatory requirements	4.000	1.8614	0.8680	7
Better resource allocation	3.967	10.8542	0.0543	9
Improved asset management	3.967	8.3088	0.1400	9
Improved communication and collaboration among stakeholders	3.933	6.1457	0.2923	11
Increased efficiency in work order management	3.933	1.8555	0.8688	11
Improved ability to manage and track maintenance costs and expenses.	3.933	4.1561	0.5272	11
Improved automation of maintenance processes	3.933	3.6003	0.6083	11
Better management of maintenance resources	3.900	7.9355	0.1598	15
Increased customer satisfaction	3.900	9.0216	0.1082	15
Reduced energy consumption and costs	3.800	4.1387	0.5296	17
Enhanced predictive maintenance capabilities	3.400	5.4227	0.3665	18
Increased flexibility and scalability	3.300	18.2087	0.0027	19
Increased transparency and accountability	3.200	15.1119	0.0099	20
Increased use of analytics for data-driven decision-making	3.167	6.1534	0.2916	21

(Source: Authors' Survey)

The Kruskal-Wallis H test outcome revealed that almost all the respondents' opinions were consistent and uniform since most of the p-values were less than 0.05; this indicated that the respondents agreed that the variables are benefits of using digital technologies for the maintenance of HEB facilities. This outcome reflects that using digital technologies for maintenance activities will gain widespread acceptance and adoption among professionals and stakeholders instead of only applying traditional methods.

3.3 Discussion of Findings

The findings on the perceived benefits of using digital technologies for maintenance management provide valuable insights into how tertiary institutions in Nigeria are experiencing these tools. The highest-ranked benefit, enhanced decision-making, highlights the significant role that digital technologies play in facilitating informed, data-driven decisions. This aligns with the work of Jasiulewicz-Kaczmarek et al. (2020), who emphasised that digital tools such as predictive analytics and real-time monitoring systems allow maintenance managers to make better decisions, leading to more effective maintenance strategies. The increased access to accurate data improves the decision-making process. It contributes to long-term cost savings by reducing downtime and improving the planning of maintenance activities, as Sala et al. (2022) have pointed out in similar studies. Another key benefit identified is the increase in productivity, which ranks second. This mirrors the findings of Madakam et al. (2019), who argue that digital technologies automate repetitive tasks and streamline workflows, freeing up time and resources for other critical activities. In the context of maintenance management, this can translate to faster repairs, optimised use of personnel, and the ability to manage larger portfolios of assets more efficiently. The significant emphasis on productivity also ties into the broader narrative of smart maintenance, as Radell & Schannon (2019) proposed, where digital tools enable more proactive and efficient operations.

Improved efficiency is another substantial benefit, highlighting the overall operational performance gains from adopting digital technologies. This result corroborates the findings of Alkhard (2024), who demonstrated that institutions leveraging digital tools such as computerised maintenance management systems (CMMS) or Building Information Modelling (BIM) experience increased operational efficiency through better resource allocation, task automation, and streamlined communication. Efficiency gains can be particularly impactful in educational institutions where budget constraints and ageing infrastructure are common challenges, as Marmo et al. (2019) argue in their analysis of digital adoption in developing countries. The study also notes improved communication and collaboration among stakeholders, which has been widely recognised in literature. Evitha (2024) emphasised that digital platforms foster better communication between maintenance teams, administrators, and external contractors, ensuring that issues are addressed promptly and effectively. The role of digital tools in facilitating stakeholder collaboration is crucial for maintaining complex facilities, and this is particularly relevant for institutions that manage large campuses with multiple buildings and systems.

However, some benefits, such as increased transparency and accountability, received a relatively lower ranking. This may indicate that while institutions recognise the value of digital technologies in improving visibility over maintenance processes, they have not fully realised these benefits. Studies by Zabalawi et al. (2024) have similarly noted that although digital tools can increase transparency, their effectiveness depends on the institution's commitment to integrating these tools into their broader operational frameworks. This finding suggests that while some institutions have implemented digital technologies, they may still face challenges in embedding them into their culture of accountability and transparency. One of the more surprising results is the lower ranking of enhanced predictive maintenance capabilities, indicating that more advanced digital technologies, such as predictive analytics, have not been fully adopted. This is consistent with the findings of O'Donovan et al. (2015), who reported that despite the availability of predictive maintenance technologies, many institutions lack the infrastructure or expertise to implement them effectively. Predictive maintenance relies heavily on data collection and analysis, which, in turn, requires investments in sensors, software, and training resources that some tertiary institutions may not yet have. The relatively low score in this area suggests that while digital technologies improve decision-making and operational efficiency, there is still room for growth in more advanced applications such as predictive analytics.

4. Conclusion and Recommendations

The study concludes that digital technologies hold significant promise for enhancing maintenance management in tertiary institutions in Nigeria. While there is a growing recognition of the benefits associated with digital tools, such as improved decision-making and increased productivity, the level of adoption of these technologies is most likely to increase. It is therefore recommended that, to maximise the benefits of adopting digital technologies in maintenance activities, institutions facing challenges in technical support should consider outsourcing technical expertise to bridge knowledge gaps. This can facilitate the effective implementation and maintenance of digital systems while providing staff with the necessary training and support. Regular engagement with all stakeholders—including staff, students, and external partners—is crucial for fostering a culture of collaboration and openness to change. Institutions should create forums for dialogue to address concerns and gather feedback on digital technology initiatives. Institutions must develop a robust financial plan to support acquiring and maintaining digital technologies. This may involve seeking grants, partnerships, and collaborations that can provide the necessary funding and resources. This study contributes to the existing knowledge on digital technology adoption in maintenance management, particularly within the context of tertiary institutions in Nigeria. The research highlights the significance of digital tools for enhanced operational efficiency by providing empirical evidence on the benefits of digital technology integration. Overall, the study is a foundational resource for future research and practice in maintenance management, paving the way for further exploration of digital technologies in educational settings.

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