Benchmarking Global Digital Technologies Adoption: Evidence-Based Lessons for the Liberian Construction Industry

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Abstract
The construction sector drives economic growth, but inefficiencies persist, particularly in developing nations like Liberia. Digital technologies (DTs) such as Building Information Modelling (BIM), Artificial Intelligence (AI), and the Internet of Things (IoT) have improved construction efficiency globally. However, Liberia struggles with adoption due to financial constraints, inadequate infrastructure, and a lack of skilled professionals. This study evaluates Liberia's state of digital technologies adoption in construction, identifying barriers and opportunities through a bibliometric analysis of 275 scholarly documents from 2015 to 2025. Findings indicate Liberia relies on traditional construction methods, hindered by low internet penetration (8%), limited electricity access (32.5% in 2022), and cybersecurity risks. Despite these challenges, initiatives like the "Building a Digital Liberia" project and international collaborations suggest potential progress. Recommended strategies include infrastructure expansion, digital training programs, financial incentives, and pilot projects. Circular economy practices, enabled by digital tracking tools, can optimise material use and sustainability. Addressing these barriers will modernise Liberia's construction sector, enhancing efficiency and global competitiveness.

Keywords
Digital technologies, construction industry, construction 4.0, industry 4.0, smart construction, sustainability, developing countries

1. Introduction

The construction sector is crucial for economic growth, making substantial contributions to both GDP and job creation around the globe (Fei et al., 2021). However, despite this contribution and opportunity provided by the industry, the sector faces persistent challenges, including inefficiencies, cost overruns, and environmental concerns. Many studies have identified that digital technologies (DTs) can help mitigate these issues through improved collaboration, automation, and data-driven decision-making (Lu et al., 2024). The adoption of digital technologies such as Building Information Modelling (BIM), the Internet of Things (IoT), artificial intelligence (AI), and blockchain has transformed construction practices globally (Lu et al., 2024; Daniela & Crisan, 2025). As a result, the construction industry has been rapidly transforming primarily due to the adoption of these digital technologies (Daniela & Crisan, 2025). These technologies aim to improve efficiency, quality, and sustainability in almost every aspect of construction. The transformation is shaped by global digitalisation, though implementation varies by region due to differences in economic conditions, technology, and regulations (Anarene et al., 2024). According to Belousov et al. (2024), digital transformation has become a necessity rather than an option for construction companies seeking to remain competitive. This process involves integrating digital technologies with business models to generate value (Belousov et al., 2024), including methodologies such as BIM, drones, automation, the IoT, and Big Data (Jamil & Fathi, 2020). In countries like the United Kingdom and Russia, for instance, the construction sector is transitioning toward mandatory information modelling technologies (Chandresh, 2025). Furthermore, sustainability is another key driver, as digital tools are increasingly used to optimise resource utilisation, reduce waste, and minimise environmental impact (Cristian et al., 2024).

Emerging technologies like Digital Twins (DT) are gaining prominence by enhancing BIM with dynamic simulations of construction processes (Muhammad et al., 2023). These digital replicas allow for better optimisation at every stage of a project. This improves decision-making and sustainability throughout a building's lifecycle. Additionally, to reduce labour costs and improve site safety, automation and robotics are being adopted to boost productivity (Mariam et al., 2020). For instance, robots are now used to execute tasks like brick laying, welding, and demolition, while automated systems streamline project management and quality control. Furthermore, data-driven decision-making is also restructuring the industry, as companies leverage vast amounts of data to optimise schedules, manage costs, and improve safety (Mouzourides et al., 2017). Cloud-based solutions further facilitate real-time collaboration among stakeholders (Mahajan, 2022), while Radio Frequency Identification (RFID) technology is gaining grip for its affordability and adaptability, particularly within Digital Twin frameworks for monitoring building conditions (Iryna et al., 2024).

Digital technologies adoption rates and focus areas vary regionally. For example, the construction sector of China is rapidly digitising, supported by government policies and investments in green innovation (Li et al., 2024). On the other hand, Russia is progressing with mandatory information modelling but contends with infrastructural limitations and cybersecurity challenges (Muhammad et al., 2023). In Europe, the UK employs multi-scale data analysis for smart urban energy management (Mouzourides et al., 2017). Developed nations lead in BIM, automation, and data analytics, though challenges persist in system integration and interoperability (Jamil & Fathi, 2020). On the other hand, developing nations face many challenges in digital technologies with negligible progress (Nosike, 2024). Overall, the construction industry's digital transformation is a complex and evolving process shaped by global trends and regional adaptations. Due to the lagging nature of the construction industry in developing countries, there have been numerous challenges hindering the adoption of trending digital technologies (Thirumal et al., 2024). These challenges span technological, organisational, economic, and regulatory dimensions. In terms of technology, the major barrier is the lack of technical expertise and knowledge among construction professionals (Bello et al., 2024). They often lack the training required to effectively use advanced tools such as BIM, Digital Twins, and IoT devices. Additionally, the lack of proper infrastructure makes it difficult to implement digital solutions on construction sites (Zheng, 2020). Issues such as poor internet connectivity, unreliable hardware and software systems, and inadequate digital support systems contribute to these challenges (Steadyman, 2024). Integration complexities also pose a challenge, as firms struggle to align new technologies with existing workflows (Huong et al., 2021). Data security and privacy concerns further impede adoption, as companies must safeguard sensitive project information from cyber threats (Huong et al., 2021).

From the organisational resistance span, confrontations to embrace change are another significant hurdle, as the construction industry is traditionally slow to adopt innovations (Thirumal et al., 2024). Furthermore, overcoming this resistance requires effective change management and clear communication about the benefits of digital tools (Aryatama et al., 2024). However, many stakeholders in developing countries are unaware of how digital technologies can improve project results. Moreover, small and medium-sized enterprises (SMEs), which dominate developing nations' sectors, face additional difficulties due to limited resources and technical expertise (Akpan et al., 2020). Ethical considerations, such as responsible AI integration, must also be addressed to ensure sustainable adoption (Shittu et al., 2024). Economic constraints further hinder digital transformation, with high initial costs for software, hardware, and training deterring investment (Ting & Yahaya, 2024). Limited access to funding worsens the issue, as financial institutions may be reluctant to support unproven technologies (Ting & Yahaya, 2024). Additionally, many firms remain uncertain about the return on investment (ROI) of digital tools (Zhou et al., 2024). This requires the need for pilot projects and case studies to showcase their economic benefits. On the other hand, regulatory challenges also play a role, as the absence of supportive government policies holds back progress (Ting & Yahaya, 2024). Bureaucratic delays and complex approval processes further discourage adoption, underscoring the need for streamlined regulations (Mahjoubi et al., 2020). Standardisation issues, such as incompatible data formats and technology platforms, create interoperability problems (Xinjie, 2024).

Like other developing nations, Liberia's construction industry faces multiple barriers to digital technology adoption. According to The Liberian Investigator News (2025) on the Monrovia Tech Summit, only 12% of the Liberian workforce possess basic digital skills. As a result, local and international construction firms struggle to implement even fundamental technologies like digital design tools or equipment tracking systems. The skills gap is similar to global trends, showing that the main obstacle to adopting digital construction methods, excluding Augmented Reality and Virtual Reality, is a lack of training (Digital Construction Today, 2025). Moreover, internet penetration remains low, with only 8% of the population having access and just a few below that experiencing reliable connectivity as of 2022 (Marie, 2022). This limits the use of cloud-based construction management tools like Building Information Modelling (BIM), and real-time collaboration platforms, which are common in more developed markets. Additionally, access to electricity is improving, but is still only at 32.5% in 2022 (The World Bank In Liberia, 2022), making it hard to power digital tools on construction sites. These infrastructure limitations create a difficult environment for widespread digital transformation in the sector.

According to the World Bank (2025), as of 2024, the Liberian construction sector is growing at 6.0% due to mining and infrastructure projects. However, it remains largely reliant on traditional methods of construction, with minimal integration of digital tools. With only 8% of the population having reliable internet access, the country's digital infrastructure is underdeveloped, further complicating technology adoption (Marie, 2022). Additionally, cybersecurity risks and a lack of skilled professionals hinder the implementation of advanced digital technologies, such as cloud-based project management systems or AI-driven analytics (Marie, 2022). International trends show that digital technologies can help promote circular economic practices, like reusing materials and reducing waste through digital tracking and Building Information Modelling (BIM) (Thirumal et al., 2024). On the contrary, these opportunities are yet to be fully explored by the construction sector of Liberia.

Many studies in developing countries have explored the adoption of digital technologies in the construction industry. However, none have evaluated the state of digital technology adoption in the Liberian construction sector. Hence, this study assesses the current state of digital technologies adoption in Liberia's construction sector, identifying key barriers and opportunities for growth. This paper explores the best international practices as well as local challenges, such as inadequate connectivity, funding shortages, and resistance to change (Onyia et al., 2024). It suggests practical strategies to expedite digital technology adoption in the Liberian construction industry. The findings aim to inform policymakers, industry stakeholders, and development partners on utilising digital technologies to enhance construction efficiency, sustainability, and competitiveness in Liberia.

2. Methods

The study aims to assess the state of digital technology adoption in the Liberian construction industry. To achieve this, bibliometrics was employed because it provides an objective, quantitative, and systematic way to map research trends, evaluate impact, and uncover knowledge gaps in large volumes of scholarly literature (Pessin et al., 2022). Scopus was selected as the primary data source for this study due to its unparalleled breadth of coverage and rigorous quality control measures. The selection of Scopus as the primary data source was based on several compelling advantages it offers over alternative databases like Web of Science, Google Scholar, and Dimensions. For instance, Scopus provides the most extensive coverage of peer-reviewed literature across all major disciplines, indexing over 27,950 active titles from more than 7,000 publishers globally (Ghosh et al., 2024). This extensive coverage is particularly valuable for studying digital technology adoption, a topic that inherently spans multiple domains, including engineering, technology, management, and social sciences. Unlike Web of Science, which has traditionally focused more on natural sciences and medicine (Bartol et al., 2014), Scopus provides better coverage in engineering and technology fields. This makes Scopus more suitable for capturing research in the construction industry. The research methodology was designed to facilitate a thorough and inclusive review of literature spanning from 2015 to 2025, starting with a foundational set of 395 documents. The study explored diverse perspectives on the benefits of digital technologies adoption in construction practices to enhance efficiency, improve teamwork, and promote sustainability. The research investigated different perspectives on the advantages of adopting digital technologies in construction practices to boost efficiency, foster collaboration, and support sustainability. A structured search strategy was employed using one of the Boolean operators (AND, OR, NOT) (Aliyu, 2017) and carefully selected keywords to systematically gather relevant academic literature. The chosen terms "digital technology" AND "adoption" AND "construction" were applied to article titles, abstracts, and keywords. This was done to ensure precision in retrieving studies that align with the research focus. Filters were used to refine the results to only include publications in the English language. These documents were selected for their significance to key subject areas essential for the study. The fields include Engineering, which produced the largest number of papers at 229, followed by Computer Science with 77 papers, Energy with 46 papers, and Environmental Science with 41 papers. As of March 2025, the initial set of documents obtained from the search was 395. To refine the search results, enhance data accuracy, and ensure relevance, the aforementioned filters were applied, reducing the documents to 275.

The bibliometric analysis was facilitated using VOSviewer. This is a software tool designed for constructing and visualising bibliometric networks, commonly used in academic and scientific research (Van Eck & Waltman, 2014). During the analysis, a minimum threshold of 10 occurrences was established for each keyword. Out of 1871 keywords identified, 35 keywords were successful in meeting the threshold to produce four clusters. According to Van Eck and Waltman (2009), this method is very important for filtering out insignificant or overly specific terms that may appear only once or twice in the dataset. This is done to avoid cluttering network maps that obscure important patterns. Therefore, this structured approach guarantees a thorough understanding of the research landscape regarding the adoption of digital technologies in the construction industry.

3. Results and Discussions

Figure 1 illustrates a map that highlights countries leading in publications on the adoption of digital technologies in the construction industry. The UK leads (59 publications), followed by South Africa (42) and Australia (41), reflecting strong engagement with construction digitisation. The presence of Nigeria (21) and Malaysia (21) highlights growing research interest in emerging economies, while advanced economies like the U.S. (31) and China (27) rank moderately. Smaller tech-driven regions like Hong Kong (11) and Singapore (9) also appear, suggesting their outsized research influence. The distribution highlights a significant research gap for Liberia, underscoring the urgency of this study on digital adoption in Liberia’s construction sector. While regional peers like South Africa and Nigeria demonstrate active engagement with construction technology research, Liberia's absence from the list reflects systemic barriers. Moreover, the prevalence of developed nations such as the UK and Australia highlights the global digital divide. This indicates that Liberia’s construction sector may lag without focused efforts to address this issue. Therefore, this study aims to bridge this gap by identifying context-specific solutions.

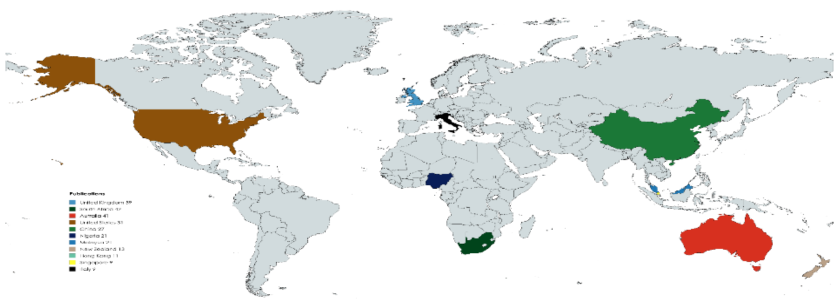

Figure 1. Publication Per Country

4. Publication Per Year

Figure 2 is a chart illustrating the number of publications on digital technology adoption in the global construction industry from 2015 to 2025. It shows a clear upward trend over time. In 2015, there were only 2 publications. The number grew irregularly, reaching 15 by 2019. From 2020 onward, the numbers increased significantly, peaking at 82 publications in 2024 before slightly declining to 43 in 2025. The figure for 2025 shows a decline to 43, likely due to incomplete data for the year rather than an actual drop in interest. This surge reflects the growing global interest and research focus on digital transformation in construction. For the research, this trend underscores the importance of leveraging international insights to inform Liberia’s digital adoption strategies. The data shows that Liberia has a chance to quickly adopt improvements by learning from global trends instead of going through slow trial-and-error methods. Furthermore, the sharp rise in publications suggests that more evidence-based best practices, case studies, and frameworks are now available. These resources can guide Liberia in overcoming adoption barriers. By analyzing these global trends, Liberia can identify successful implementation models and avoid common pitfalls. This will help accelerate its own digital transformation in the construction sector, ultimately improving efficiency, sustainability, and competitiveness.

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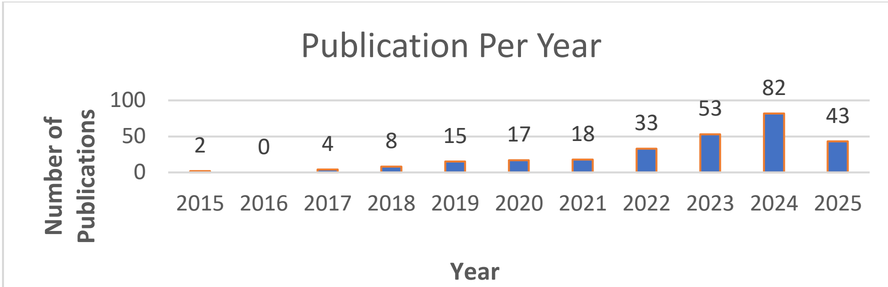

Figure 2: Publications per year

4. Publication Per Occurrence Of Keywords

With a minimum occurrence threshold of 10 applied to guarantee sufficient coverage, just 35 keywords out of the initial 1871 satisfied this condition. These keywords were subsequently organised into four (4) distinct clusters, shown in Figure 3.

Cluster 1. Digital Construction, denoted in red, includes construction 4.0, the construction industry, construction sectors, decision-making, digital technologies, digital transformation, digitalisation, industry 4.0, barriers, and technology adoption. According to Ding et al. (2019), digital construction refers to the utilisation of advanced technologies like BIM, AI, and IoT to improve efficiency, collaboration, and sustainability in building projects. It transforms traditional construction through data-driven planning, automation, and real-time monitoring. Using insights from global perspectives, the implementation of digital construction technologies in Liberia has the potential to transform critical challenges. This transformation could significantly impact the country's construction industry. These challenges include, but are not limited to, inefficiency, resource constraints, and limited access to advanced methodologies. Digital tools like Building Information Modelling (BIM), IoT sensors, and modular construction systems can optimise project planning, reduce waste, and enhance safety (Daniela & Crisan, 2025). In Liberia, infrastructure development is hindered by geographic and climatic barriers, such as prolonged rainy seasons (Mobile World Live, 2024). Digital solutions like ZTE's modular "Lego-type" towers and solar-powered EcoSites demonstrate how rapid, flexible deployment can bridge gaps in rural connectivity and construction timelines (Mobile World Live, 2024). Furthermore, digital construction tools, such as Building Information Modelling (BIM), cloud-based project management software, and AI-driven analytics, can significantly enhance project planning, execution, and monitoring (Lu et al., 2024). These tools help reduce delays and cost overruns that are common in traditional construction methods, which are dominant in Liberia. Moreover, Liberia faces challenges like poor connectivity, skills gaps, and underdeveloped infrastructure (Marie, 2022; The World Bank in Liberia, 2022). Digitalisation can help overcome these barriers by improving collaboration, optimising resource use, and enabling data-driven decision-making. Thus, assessing and accelerating digital adoption in Liberia's construction sector is not just about technological advancement but also about fostering economic resilience and inclusive growth.

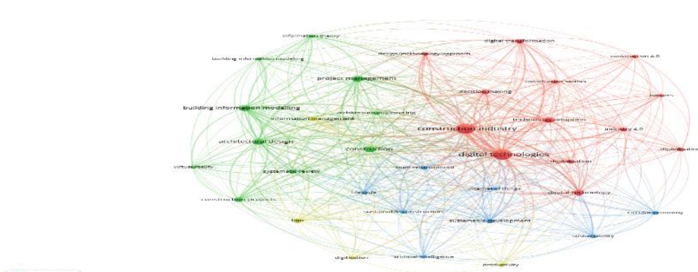

Figure 3. Occurrence network visualisation map (authors')

Cluster 2. Smart Engineering, denoted in green, constitutes virtual reality, IoT, architectural design, architecture engineering, construction, construction projects, information theory, and project management. Smart Engineering refers to the integration AI, IoT, and automation to optimise systems, enhance efficiency, and enable data-driven decision-making (Pereira et al., 2020). It has been identified as a transformative force that is crucial to the digital evolution of the Liberian construction industry. The integration of smart technologies like artificial intelligence (AI), the Internet of Things (IoT), and machine learning to optimise processes, enhance decision-making, and improve

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infrastructure quality (Tien, 2017). Furthermore, Liberian construction firms can overcome challenges like inefficiencies, cost overruns, and safety risks by using smart engineering solutions (Rane, 2023). These solutions include automated design software, real-time project monitoring systems, and predictive maintenance tools (Cinar et al., 2022). These technologies also enable data-driven project management, reducing human error and ensuring that limited resources are used effectively. Additionally, smart engineering supports sustainable construction practices by minimising material waste and energy consumption (Lin et al., 2024). This is critical in a resource-constrained environment like Liberia. However, the successful adoption of these technologies depends on overcoming barriers such as inadequate digital infrastructure, skills gaps, and resistance to change (Marie, 2022). Ultimately, embracing smart engineering will not only modernise Liberia’s construction industry but also enhance its competitiveness, resilience, and contribution to national development goals.

Cluster 3. Circular Construction, denoted in blue, constitutes artificial intelligence, built environment, circular economy, internet of things, life cycle, sustainability, sustainable construction, and sustainable development. Circular construction is a sustainable building approach that focuses on reducing waste and reusing materials to minimise environmental impact (Pereira et al., 2020). Circular construction is very important for Liberia's construction industry. It helps meet global sustainability goals and addresses local issues like resource scarcity, waste management, and environmental degradation (Garg, 2023). By transitioning from the traditional linear "take-make-dispose" model to a circular approach that emphasises reuse, recycling, and regeneration of materials (Elisha, 2020), Liberia can reduce its reliance on imported construction materials. This is where digital technologies play a pivotal role in enabling this transition. For instance, Building Information Modelling (BIM) and material passports can track reusable materials throughout their lifecycle, while AI and blockchain can optimise material recovery and ensure transparency in circular supply chains (Keles et al., 2025). However, Liberia faces significant barriers to adoption, including limited digital infrastructure and low internet penetration for circular practices (Marie, 2022). Evaluating the current level of digital adoption is crucial for identifying gaps and utilising technologies such as IoT-enabled waste sensors and digital marketplaces for secondary materials. These tools could assist Liberia in addressing its resource constraints and developing a more resilient and sustainable construction sector. Without integrating circular principles, Liberia risks perpetuating inefficient and costly construction methods. Additionally, failing to adopt the digital tools that enable these principles could hinder long-term development and lead to environmentally damaging practices.

Cluster 4. Digital Information Productivity, denoted in yellow, encompasses BIM, digitisation, information management, and productivity. Digital Information Productivity has been identified as one of the cornerstones essential for modernising Liberia’s construction industry. In Liberia, where manual processes and inefficiencies persist, digital productivity tools can address chronic challenges such as material waste, delayed timelines, and budget overruns. For example, BIM-enabled 3D modelling allows precise material calculations, reducing waste (Junussova et al., 2023), while IoT sensors can monitor on-site progress and safety, enabling proactive decision-making (Aryatama et al., 2024). However, to fully harness digital productivity, the industry must prioritise investments in ICT infrastructure, workforce training, and policy frameworks that incentivise technology adoption. Without these steps, the sector risks perpetuating inefficiencies that hinder Liberia’s infrastructure development goals and economic resilience, underscoring the urgency of assessing and accelerating digital adoption.

The results highlight that a significant digital divide exists in the adoption of construction technology globally. While nations such as the UK, South Africa, and Australia have advanced digital construction practices, Liberia remains absent from this research and practice landscape. This gap reflects systemic barriers, including limited connectivity, inadequate workforce digital skills, and financial constraints. Nevertheless, the growing global momentum in digital construction provides Liberia with a chance to learn from established practices and bypass lengthy trial-and-error processes. A practical entry point could be the adoption of “Digital Information Productivity” tools, such as Building Information Modelling (BIM). However, this requires moderate investment but delivers substantial efficiency gains. Once established, these tools can create a foundation for more advanced applications such as AI-driven analytics, IoT-based monitoring, and smart engineering solutions. Aligning digital adoption with circular construction principles would further reduce dependence on costly imports and promote resilience through data-driven resource optimisation. Without deliberate and evidence-based strategies, Liberia risks lagging in construction innovation; however, a phased approach beginning with accessible digital tools provides a viable path toward long-term competitiveness.

5. Conclusions

The Liberian construction industry remains at an early stage of digital technology adoption. It faces persistent barriers such as poor digital infrastructure, limited internet access, cybersecurity risks, and a shortage of professionals skilled in emerging technologies. While global trends show the transformative role of digital tools in improving productivity, efficiency, and sustainability, Liberia lags behind in integrating these innovations. With only about 8% of the

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population connected to the internet, opportunities for real-time collaboration, cloud-based project management, and data-driven decision-making remain extremely limited. Reliance on traditional construction methods has led to recurring cost overruns and delays. This further weakens the sector's competitiveness. Hence, the consequences of inaction are significant. Without accelerated digitalisation, Liberia risks entrenching inefficiencies that will limit its ability to meet future infrastructure demands. This will hinder economic growth, discourage foreign investment, and reduce competitiveness within the regional construction market. Also, failure to modernise will undermine efforts toward sustainability, as waste reduction and circular economy practices are increasingly enabled by digital tools such as BIM and the IoT. In the long term, a stagnant construction sector could constrain national development, exacerbate unemployment, and widen the gap between Liberia and digitally advancing economies. Thus, some initiatives, such as the government's "Building a Digital Liberia" project and international collaborations like Cybastion's planned data centre, indicate a growing awareness of the need for transformation. However, a more comprehensive and coordinated approach is required to drive tangible change. First, strengthening digital infrastructure through expanded internet connectivity and reliable power supply is essential. These improvements will provide the foundation for the adoption of BIM, IoT applications, and cloud-based project management systems. Second, targeted training and capacity-building programs must be developed to improve digital literacy among construction professionals. Partnerships with universities, training centres, and international organisations can play a key role in bridging this skills gap. In addition, policy support through financial incentives such as subsidies, tax relief, or specialised funding schemes will encourage firms to invest in digital tools. Also, public–private partnerships should be leveraged to accelerate infrastructure development, promote innovation, and facilitate knowledge exchange. Pilot projects demonstrating the benefits of digitalisation, such as improved project delivery times, cost savings, and enhanced sustainability, would further encourage adoption across the industry. Lastly, the path to digital transformation in Liberia's construction industry requires a deliberate strategy that addresses systemic challenges, builds professional capacity, and drives innovation. Without this shift, the sector risks falling further behind global standards, jeopardising both its economic relevance and its contribution to sustainable national development.

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