

Strategies for improving the adoption of digital technologies in the construction industry

Lesiba George Mollo¹

¹Department of Built Environment, Central University of Technology, Free State, South Africa

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Abstract

The construction industry can significantly boost productivity, efficiency, collaboration, and project performance through the adoption of digital technology. Despite these advantages, integration in many provinces of South Africa remains slow and inconsistent. This study aims to develop a strategy for improving digital technology adoption within the construction industry. A qualitative research design was employed, and data were collected through semi-structured interviews with 17 construction professionals in South Africa's Free State Province. Thematic analysis was used to identify and interpret key themes related to digital technology adoption. Findings indicated diverse levels of familiarity and engagement with digital technologies among participants, alongside several influencing factors. Based on these insights, a four-step strategy was developed: (1) Defining clear goals for digital technology implementation; (2) Investing in appropriate digital technologies; (3) Fostering collaboration and communication among project stakeholders; and (4) Prioritizing education and skills development. This proposed strategy offers a practical, context-specific framework for construction organizations to facilitate digital transformation and enhance operational efficiency. By moving beyond merely identifying adoption barriers, this study contributes to the growing knowledge on construction digitalization by providing an empirically grounded strategy to support effective digital technology implementation, ultimately promoting improved productivity, competitiveness, and long-term industry development.

Keywords: Construction industry; Digital technology adoption; Digital transformation; Technology implementation strategy; South Africa

1 Introduction

The construction industry is vital for national development, providing essential infrastructure that supports economic growth and societal well-being. As Pheng and Hou (2019) note, it spans all three economic sectors: natural resource extraction (primary), manufacturing and transformation of materials (secondary), and professional services like project management and engineering (tertiary). This broad involvement means that the industry's performance is intrinsically linked to a nation's overall economic health. Therefore, sustained economic growth requires the construction industry to prioritize and adopt digitalization.

Digitalization involves transitioning to digital business models or, more broadly, integrating digital technologies to transform operations, enhance value creation, and expand revenue streams (Nikmehr et al., 2021). For the construction industry, adopting digital technologies is crucial for improving performance and productivity (Parusheva and Aleksandrova, 2021). This digital transformation is being driven by recent advancements in innovative building materials, sophisticated software, and modern construction techniques (Akinshipe et al., 2022). Furthermore, the growing interest in automation has fueled the adoption

of digital technologies due to their potential to optimize processes and reduce inefficiencies (Cardinali & De Giovanni, 2022). Empirical evidence confirms that these technologies enhance productivity, safety, and sustainability in construction (Nucci et al., 2023).

Historically, technological advancements have correlated with increased productivity across industries, particularly since the mid-twentieth century (Perera et al., 2023). In the context of the Fourth Industrial Revolution (Industry 4.0), industries are expected to leverage digital technologies to create safer, more resilient, intelligent, and sustainable systems. Despite this global trend, construction remains one of the least digitalized industries worldwide, ranking second to last (Rinchen et al., 2024). While digital technologies have significantly transformed sectors like manufacturing, agriculture, and retail, construction has been comparatively slow to adopt these innovations (Perera et al., 2023).

This slow adoption rate is exacerbated by the construction industry's inherent structural and operational challenges. Daniel et al. (2024) observe that many firms still rely on traditional practices that have remained unchanged for decades. Brozovsky et al. (2024) attribute the limited uptake of digital technologies to factors such as industry fragmentation,

¹ Corresponding Author

Email address: lmollo@cut.ac.za

the project-based nature of construction, and the temporary and dynamic composition of supply chains. These characteristics hinder the standardization and scalability necessary for effective digital transformation.

The South African construction industry continues to face significant challenges, including inefficiencies, project delays, cost overruns, and safety concerns, despite its important contributions to employment and economic growth (Aigbavboa et al., 2022). The limited adoption of digital technologies further constrains the industry's ability to improve project delivery, enhance productivity, and remain globally competitive (Aghimien et al., 2023). Although previous studies have highlighted the benefits of digitalization and identified barriers to its adoption, such as high implementation costs, inadequate technical skills, limited organizational readiness, and resistance to change these studies have largely focused on diagnosing challenges rather than developing practical strategies to address them. Moreover, there is a scarcity of research proposing context-specific frameworks or strategies for promoting digital technology adoption within South African construction firms, particularly in provinces like the Free State, where digital transformation remains relatively underexplored.

Against this backdrop, the central problem addressed in this study is the slow and uneven adoption of digital technologies within the South African construction industry, which continues to undermine operational efficiency, productivity, and long-term sustainability. While existing research has improved understanding of the barriers to digital adoption, limited attention has been given to translating these insights into actionable strategies that industry stakeholders can implement. To address this gap, this study develops a strategy for enhancing digital technology adoption in the construction industry, derived from empirical evidence obtained from construction professionals in the Free State Province. Beyond merely identifying barriers, the proposed strategy provides a structured and practical guide for overcoming adoption challenges, supporting organizational readiness, and facilitating the transition toward more digitally enabled construction processes. In doing so, the study contributes both theoretical and practical insights to the growing discourse on digital transformation in the South African construction sector.

2 Literature Review

Digital technologies offer the potential for application across all stages of a construction project, from inception through operation and maintenance (Schnell et al., 2023). Integrating these technologies into construction processes has been linked to improved efficiency in project delivery, manifesting as reduced time, enhanced decision-making, lower material costs,

and more effective resource utilization. Moreover, the adoption of digital technologies across various industries has yielded significant benefits, such as cost reduction, improved service delivery, process optimization, and faster turnaround times (Aghimien et al., 2023). These advantages are particularly pertinent given the construction industry's ongoing struggles with inefficiencies, delays, and cost overruns.

The primary goal of applying digital technology in construction is to enhance performance and productivity. Kineber et al. (2023) further emphasize that digital technologies are crucial for achieving these objectives by optimizing construction processes while upholding necessary performance standards. Consequently, there has been increasing research into the impact of digital technologies within the construction industry (Zhang et al., 2023). These studies consistently show that digital technologies contribute to multiple aspects of construction performance, including planning and design, productivity, project management, health and safety, sustainability, and cost and time efficiency.

For example, Building Information Modeling (BIM) has become a fundamental digital tool in the planning and design phase. BIM enables the creation of integrated digital models that improve collaboration, visualization, and analysis throughout the project lifecycle (Sompolgrunk et al., 2024). These models go beyond three-dimensional representations to incorporate scheduling (4D), cost estimation (5D), energy performance (6D), and facility management (7D). Complementing BIM, Virtual Reality (VR) allows stakeholders to interact with simulated project environments before construction begins, thereby improving comprehension and facilitating more informed decisions (An et al., 2023).

Digital technologies have significantly enhanced construction site operations by improving productivity and efficiency. Unmanned aerial vehicles (UAVs), or drones, provide rapid and accurate data collection for surveying, progress monitoring, and safety inspections (Jeelani and Gheisari, 2021). Automation and robotics have introduced new capabilities for tasks such as bricklaying, concrete placement, and material handling, increasing precision, safety, and operational efficiency (Liu et al., 2024).

Digital technologies have also transformed construction project management. The Internet of Things (IoT), utilizing networked sensors, enables real-time data collection and monitoring across construction sites. This facilitates improved safety management systems, offering enhanced resource allocation, performance monitoring, and real-time safety surveillance (Khurshid et al., 2023; Mollo, 2024b). In health and safety, wearable technologies like smart helmets, smartwatches, and exoskeletons monitor

workers' health and site conditions, improving safety outcomes and communication (Nnaji et al., 2021; Mollo, 2024a). Furthermore, artificial intelligence (AI) supports advanced applications such as predictive maintenance, real-time monitoring, generative design, and automated equipment operation, leading to better decision-making and safer construction environments (Daniel et al., 2024).

From a sustainability perspective, digital technologies like 3D printing and smart materials offer innovative solutions for more efficient and environmentally responsible construction. 3D printing enables rapid, cost-effective production of building components, reducing material waste and construction time (Puzatova et al., 2022). Smart materials enhance building performance with features such as self-healing properties, improved energy efficiency, and real-time structural monitoring (Nilimaa and Zhaka, 2023). For cost and time performance, prefabrication and modular construction methods facilitate off-site production, which improves quality control, reduces on-site labor, and accelerates project timelines (Li et al., 2023). Digital twins further strengthen project delivery by providing dynamic, data-driven virtual representations of construction projects, supporting planning, monitoring, and execution (Opoku et al., 2021).

The literature demonstrates that digital technologies significantly enhance construction project performance through improved planning and design, productivity, project management, health and safety, sustainability, and cost and time efficiency. However, despite these recognized benefits, digital technology adoption in the South African construction industry faces organizational, financial, and skills-related challenges. While previous studies have extensively identified the benefits and barriers to digital technology adoption, limited attention has been given to developing practical, context-specific strategies for implementation. Therefore, this study proposes a conceptual framework to enhance digital technology adoption based on four interrelated strategic pillars: defining clear goals for digital technology implementation, investing in appropriate digital technologies, fostering collaboration and communication among stakeholders, and prioritizing education and skills development. These pillars are expected to collectively support digital transformation and, consequently, improve project performance, productivity, sustainability, and competitiveness within the South African construction industry.

3 Research Methodology

This study aims to develop a strategy for enhancing the adoption of digital technologies in the construction industry. To achieve this, a qualitative research approach, as recommended by Saunders et al. (2023), was employed. This approach provided an in-depth

understanding of construction professionals' perceptions, experiences, and practical insights regarding digital technology adoption. Consequently, this study adopted an interpretivist research paradigm, seeking to interpret participants' views within their real-world contexts (Saunders et al., 2023). Furthermore, a cross-sectional research design (Creswell & Creswell, 2023) was used, with data collected over three months (July–September 2024) from construction professionals in the Free State Province of South Africa.

Qualitative data were collected through semi-structured interviews, a method well-suited for exploring participants' experiences, perceptions, and insights in depth (Creswell & Creswell, 2023). The interview guide was developed from themes identified in the literature on digital technology adoption in construction. It focused on current digital practices, perceived benefits, adoption barriers, and strategies for improving technology uptake within the South African construction industry. The guide consisted of two sections: the first collected demographic information, while the second explored issues related to digital technology adoption. A total of 17 construction professionals were interviewed at their respective workplace environments (construction site offices) to ensure responses were informed by active project experiences. Interviews lasted approximately 30 minutes, were audio-recorded with participants' consent, and continued until data saturation was achieved, as no new themes or insights emerged from subsequent interviews. Participants were informed about the study's purpose and assured of confidentiality and anonymity to encourage candid responses.

A purposive sampling technique was adopted to select information-rich participants who possess relevant knowledge and experience regarding the phenomenon under investigation (Saunders et al., 2023). Accordingly, participants were selected based on their direct involvement in construction project execution and their familiarity with digital technologies in the Free State construction sector. The inclusion of professionals occupying diverse roles within the construction industry enhanced the breadth and richness of perspectives obtained. To ensure the trustworthiness of the findings, all interviews were transcribed verbatim and subjected to thematic analysis. The coding process (Table 1) involved repeated review of the transcripts, systematic theme development, and verification of the consistency of interpretations through continuous comparison of emerging themes with the original data, thereby enhancing the credibility and dependability of the findings.

Thematic analysis, following Creswell & Creswell's (2023) recommendations, was employed to analyze the collected qualitative data. This approach was chosen

Table 1: Demographic profile of interviewees

Interviewees	Coding	Number (No)
GIS Operators	DSP 1	1
Quantity Surveyors	DSP 2	6
Project Managers	DSP 3	3
Electrical Engineers	DSP 4	1
Civil Engineers	DSP 5	3
Construction Managers	DSP 6	1
Safety Officers	DSP 7	1
Town Planners	DSP 8	1
Total		17

for its ability to facilitate the identification and interpretation of patterns within the data. The analytical process began with transcribing recorded interviews, followed by systematically coding the transcripts to identify meaningful data segments (Creswell & Creswell, 2023). These codes were then grouped into broader categories and refined into key themes, which represented recurring patterns in participants' responses. This process ultimately revealed two principal themes, highlighting critical issues concerning digital technology adoption in the construction industry. Consequently, the thematic analysis yielded contextually grounded insights, informing the study's contribution to identifying strategies for enhancing digitalization within the South African construction sector. Prior to data collection, ethical clearance for the study was obtained from the relevant institutional ethics committee. All participants received an informed consent form detailing the study's purpose, their voluntary participation, confidentiality provisions, and their right to withdraw at any stage before the interviews were conducted.

4 Findings and Discussion

This research yielded results that fall into two main themes: first, the construction industry's current level of digital technology awareness; and second, a strategy for improving digital technology adoption within the industry.

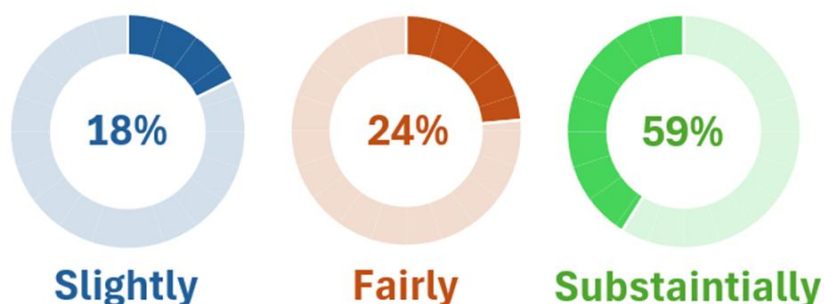
4.2. The construction industry's current level of digital technology awareness

During the interviews, participants described their involvement in construction projects using digital technologies. This allowed for an assessment of their familiarity, which was then classified as slight, fair, or substantial. The distribution of these classifications is presented in Figure 1.

As Figure 1 illustrates, most participants reported substantial familiarity with digital technology. Specifically, 59% (n = 10) indicated substantial involvement in construction projects incorporating digital technologies. In comparison, 24% (n = 4) reported fair involvement, and 18% (n = 3) reported slight involvement. These results suggest that while most construction professionals have considerable experience with digital technologies, a segment still has limited exposure.

Interviewees were asked to elaborate on their self-assessed familiarity with digital technology in the construction industry. Key comments include:

DSP_2, a quantity surveyor at a cost consulting firm, rated his familiarity with digital technology as slight. *"He noted that his company recently acquired an Autodesk BIM 360 license. While his knowledge of the software is limited to basic functions, he finds it useful."*

**Figure 1:** Level of digital technology familiarity among construction professionals.

The cloud-based storage of cost information enhances his efficiency, allowing him to access project data, review activities, and advise clients on project costs without extensive tender documentation."

DSP_8, a town planner, assessed her level of involvement as fair. *"She explained that she received drone operation training and applies this technology in her work, using drones to conduct aerial surveys for site layout plans on construction projects."*

DSP_5, a civil engineer, reported substantial involvement in projects utilizing digital technology. *"He described his experience operating a wastewater treatment plant, stating that sensors are crucial for monitoring water quality, as visual assessment alone is insufficient."*

These responses suggest a growing recognition of the benefits of digital technologies within the South African construction industry. This is further supported by 59% of interviewees reporting substantial participation in projects involving digital technology, as well as by DSP_5's example of using sensors for water quality evaluation.

4.3. A strategy for improving the adoption and use of digital technologies in the construction industry

Clear guidelines for digital technology implementation are crucial in the South African construction industry, which involves multiple stakeholders and remains highly labour-intensive. Collaboration and communication frequently emerged as key factors influencing digital technology adoption. For example, DSP_3 emphasized digital technologies for improving collaboration among consultants and contractors, while DSP_5 highlighted leveraging digital tools for enhanced coordination among project teams. Supporting this, DSP_2 noted that BIM improves collaboration via a shared cloud-based platform, facilitating timely and cost-effective project delivery. These findings informed the inclusion of fostering collaboration and communication as a strategic component of the proposed framework.

Interviews also revealed concerns regarding the suitability and implications of specific digital technologies within the South African context. DSP_6 highlighted that the construction industry is a major employer of low-skilled and unskilled workers, cautioning that increased automation and robotics may reduce employment opportunities. This suggests that digital technology adoption should balance productivity improvements with socioeconomic realities. Consequently, defining clear goals for digital technology implementation emerged as the first strategic step, aligning technology adoption with project requirements, organizational priorities, and broader employment considerations. Similarly, the recommendation to invest in appropriate digital technologies" stemmed from participants' emphasis on adopting technologies that provide immediate and practical value. For instance, DSP_6 recommended starting with affordable technologies like Autodesk BIM 360 before progressing to more advanced solutions, emphasizing phased and context-sensitive investment decisions.

Another recurring theme was the need for capacity building and digital skills development. Despite acknowledging the potential benefits of technologies like BIM, artificial intelligence, and real-time monitoring, concerns were raised regarding limited training opportunities and inadequate organizational support. DSP_6 specifically argued that clients and contractors should actively promote digital technology training and expressed personal interest in acquiring digital skills despite limited employer support. Furthermore, DSP_1 and DSP_7 highlighted the value of digital technologies for enhancing health and safety management through real-time monitoring, artificial intelligence, and CCTV-based compliance tracking. However, participants recognized these benefits are only realized if employees possess the necessary competencies. These findings directly informed the inclusion of "education and skills development" as the fourth strategic component of the framework.

Based on these empirically derived themes, Figure 2 presents a four-step strategy for enhancing digital technology adoption in the construction industry. This



Figure 2: Four-step strategy for enhancing digital technology adoption in the construction industry.

strategy emerged from participants' experiences and recommendations regarding digitalization challenges and opportunities, rather than being a generic model. The first step, "defining clear goals for digital technology implementation," addresses aligning technology adoption with organizational objectives and local labor market realities. The second step, "investing in appropriate digital technologies," responds to calls for practical, phased technology investments matching organizational capabilities. The third step, "fostering collaboration and communication," reflects the widespread recognition of digital technologies as enablers of information sharing and coordination among project stakeholders. Finally, "prioritizing education and skills development" addresses the critical need to build workforce capacity and support effective technology utilization. Collectively, these interconnected steps provide a contextually grounded strategy to assist construction organizations in overcoming adoption barriers and achieving a more coordinated transition towards digitalization.

The strategy outlined in Figure 2 was developed directly from the themes and recommendations that emerged from the interview data. Through thematic analysis, participants consistently highlighted four critical requirements for successful digital technology adoption in the construction industry. First, concerns regarding the selection, purpose, and potential implications of digital technologies particularly their impact on employment underscored the need for clearly defined implementation goals. Second, participants emphasized the importance of investing in suitable and affordable technologies that align with organizational capabilities and project needs. This led to the "investment" component of the strategy. Third, the recurring emphasis on BIM, cloud-based information sharing, and coordination among consultants and contractors demonstrated the importance of

collaboration and communication in facilitating digital transformation. Finally, participants repeatedly identified inadequate training and limited digital competencies as major barriers to adoption, resulting in the inclusion of "education and skills development" as a core strategic pillar. Therefore, the proposed strategy is not a generic framework drawn solely from the literature; rather, it is an empirically grounded model developed from the lived experiences, challenges, and recommendations of construction professionals operating within the South African construction industry.

5 Conclusion

This study aimed to develop a strategy for enhancing the adoption of digital technologies in the construction industry. The results revealed the level of familiarity with digital technologies among construction professionals, with most interviewees demonstrating familiarity. For example, one respondent described how their water treatment facility utilizes sensors to assess water quality. A strategy was established to improve digital technology adoption in the construction industry, comprising the following key actions: (1) defining clear goals for digital technology implementation; (2) investing in appropriate digital technologies; (3) fostering collaboration and communication; and (4) prioritizing education and skills development. A limitation of this study is that the qualitative data was derived from only seventeen interviews. Therefore, future research should prioritize action research with a larger sample to validate the proposed strategy for improving digital technology adoption in the construction industry and provide recommendations for its implementation in South Africa.

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