

Bridging the digital divide: Unpacking the roadblocks to innovative risk management in construction

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ARTICLE INFO	ABSTRACT
<i>Article history:</i> Received June 22, 2025 Received in revised form May 18, 2026 Accepted August 17, 2026 Available online September 01, 2026 <i>Keywords:</i> Construction risk Digitalisation Digital technology adoption Digital transformation Risk management *Corresponding author: Olushola Akinshipe University of Johannesburg Email: sholaakinshipe@gmail.com ORCID: https://orcid.org/0000-0002-0855-6455	<i>The integration of digital technologies in the construction industry can improve risk management, productivity, efficiency, and decision-making. However, adoption remains limited, particularly in developing countries. This study investigates the key barriers hindering the use of digital technologies for risk management in the building industry. A quantitative research approach was adopted, using descriptive statistics and exploratory factor analysis based on data collected from construction professionals. The factor analysis grouped the barriers into four major categories: data security and internet cost concerns, financial and workforce barriers, economic and labour market concerns, and organisational and cultural resistance. The findings show that digital adoption is affected by interconnected challenges, including weak digital infrastructure, financial constraints, skills shortages, and resistance to change. Addressing these barriers requires leadership commitment, staff training, improved digital infrastructure, stronger cybersecurity, and supportive policies to reduce connectivity costs. The study concludes that while digital tools offer significant benefits for construction risk management, their successful implementation depends on coordinated organisational and industry-level change.</i>

Introduction

Risk and safety in construction are more than a checklist or a set of regulations. They concern people's lives, hopes, and livelihoods. Every day, thousands of workers step onto sites around the world, trusting that careful planning and vigilant oversight will keep them safe. Yet the reality is that construction still claims a life every nine minutes, with tens of thousands of fatalities recorded each year (Konda, Tiesman, and Reichard 2016). From the constant hum of cranes to the towering heights of scaffolding, hazards are present at every step, and a single misstep can transform ambition into tragedy. (Cimellaro and Domaneschi 2017; Sousa, Almeida, and Dias 2014).

Traditional safety management approaches tend to be reactive and fragmented. They fall short

of addressing the dynamic hazards inherent in construction environments (Asadzadeh et al. 2020). In response, the industry has begun implementing a variety of digital technologies (DTs) to streamline design, construction, and project management. This shift addresses persistent challenges such as risk mitigation, low productivity, and poor performance (Martin Loosemore 2014). Evidence suggests that these emerging technologies can significantly enhance efficiency, productivity, and overall safety (Chen et al. 2022). By embedding risk assessment and mitigation strategies into both planning and execution phases, DTs enable proactive hazard detection and management, thereby strengthening the safety framework across projects (Akram et al. 2022).

Despite these benefits, the adoption of digital tools in construction remains sluggish, and uptake



varies widely across different technologies (Chowdhury, Adafin, and Wilkinson 2019). A World Economic Forum report highlights the sector's historical reluctance to embrace innovation, a disposition that has contributed to stagnant productivity over the past fifty years (Renz et al. 2016). Nevertheless, expanding DT adoption is increasingly viewed as vital for national economic growth in many regions (Duncan, Kingi, and Brunsdon 2018). To accelerate this shift, it is essential to identify and overcome the barriers impeding digital uptake (Muñoz-La Rivera et al. 2021). Research into these obstacles holds considerable promise for guiding strategies that support the smoother integration of DTs in construction (Aiyetan and Das 2023).

While numerous studies have examined information technology-driven innovations in construction, such as Ahuja et al. (2010) investigation of ICT adoption factors in India and Salzano et al. (2024) focus on BIM for risk management, most concentrate on a single technology. Work by Chan, Olawumi, and Ho (2019), Badamasi et al. (2021), and Bademosi and Issa (2021) further illustrates this trend. A notable gap therefore exists in the literature regarding the broader challenges and drivers that influence the uptake of digital systems, particularly those aimed at risk management in the construction industry. This raises an important question and requires establishing the barriers to the adoption of digital technologies for risk management in construction. To address this question, this study adopts a quantitative, multi-variate analysis that moves beyond assessing a single technology to examine the full landscape of impediments facing the industry. Ultimately, this study seeks to fill that gap by systematically identifying the impediments to adopting digital technologies for risk management in the construction industry.

Risk management and the digital transformation of construction

Risk management is the systematic process of setting priorities, identifying and analysing risks, and implementing actions to address them (Young and Tomsaki 2002). Hung and Tangpong (2010) describe it as the decision of whether to accept, eliminate, reduce, or transfer a known risk. Sanchez et al. (2009) expand on this, noting that risk management involves identifying hazards that affect project cost and schedule, quantifying their time and cost implications, planning

proactive mitigation measures, selecting appropriate control techniques, and assigning risks to the relevant contractual parties. The ultimate goal is to detect potential problems before they arise, enabling responses to be planned and implemented throughout the project life cycle (Iqbal et al. 2015). Achieving this requires clear and reliable data, with all relevant project information available in an unambiguous form to support risk-informed decision-making and deliver the best value in cost, time, and quality (Gransberg et al. 2018).

Digitalisation offers a powerful means of strengthening this risk management process. Despite its potential to enhance many aspects of construction and yield improved long-term outcomes (Koscheyev, Rapgof, and Vinogradova 2019), the industry continues to lag behind other sectors in digital adoption (Osunsanmi, Aigbavboa, and Oke 2018). A lack of innovation, limited technical progress, and low investment in research and development remain persistent constraints (Oesterreich and Teuteberg 2016). Alaloul et al. (2018) group the sector's digitalisation potential into four categories: digital data, digital access, automation, and connectivity. Castagnino, Rothballer, and Gerbert (2016) further argue that digitalisation can transform all three primary phases of construction, namely design and engineering, construction, and operation, thereby significantly boosting productivity.

Nevertheless, realising this potential remains a considerable challenge. Many firms struggle to develop coherent digital transformation plans because the process is both new and complex (Nikmehr et al. 2021). Voordijk and Adriaanse (2016) note that success depends on teams capable of managing digital change effectively, and that digitalising an established firm is inherently more difficult than building a new digital company from the ground up. Firms, therefore, require a clear strategy that defines objectives, roadmaps, actions, and methods of assessment (Lipsmeier et al. 2020). As Tanga et al. (2021) observe, a wide range of digital advances holds the potential to boost both productivity and affordability in construction. Harnessing these advances, however, first requires overcoming the structural and cultural barriers that continue to slow the industry's digital progress. Ultimately, the degree to which construction firms embrace digital transformation will determine how effectively they are able to

identify, assess, and manage the risks that threaten the safety and success of their projects.

Inhibitors of digital risk management progress in construction

The progress of digital risk management in construction is limited by low awareness and poor understanding of available digital tools, especially in developing countries (Dixit et al. 2021; Malykhin et al. 2026). Technologies such as blockchain are still viewed as unfamiliar, and their adoption is slowed by limited knowledge of their functions and value (Wang et al. 2017). Similarly, although building information modelling can improve coordination and planning, its uptake remains low due to limited understanding of user roles and expected benefits (Gu and London 2010). Even though digital risk management tools can improve safety, cost control, and scheduling outcomes, many firms remain sceptical about their ease of use and practical benefits (Tanga et al. 2021).

Resistance to change also slows digital adoption in construction. While sectors such as banking, manufacturing, and retail have embraced digital tools to improve efficiency and competitiveness, construction firms have been slower to adapt (Aghimien et al. 2018). This resistance often comes from within organisations, as workers may fear new technologies and prefer familiar work routines (Lojda et al. 2020; Mitchell and Demian 2011). The traditional structure of the construction industry, which involves many actors, complex processes, and fragmented operations, further limits the adoption of digital methods (Muñoz-La Rivera et al. 2021). Organisational culture also plays a key role because it shapes how employees think, behave, and respond to change (Morcos 2018). Therefore, companies that lack a digital mindset may struggle to implement new processes effectively (Lojda et al. 2020).

Leadership support is another important factor. Digital innovation often involves risk, uncertainty, and new ways of working. For this reason, top management must provide direction, approval, funding, and resources. Leaders are central to managing change and improving service quality (King'oo 2017). Management support is also essential for approving innovation projects, allocating finances, and ensuring that adequate resources are available (Rodríguez, Pérez, and Gutiérrez 2008). In addition, managers must encourage staff, support communication,

promote cooperation, and provide sufficient time and training for users (Borhani 2016). Without strong leadership, digital tools and innovative risk management practices may fail to gain acceptance.

A lack of skilled workers further affects digital risk management progress. Skilled workers are those with the knowledge, ability, and training needed to perform tasks competently (Ganesh and Tyagi 2021). However, construction firms often struggle to attract and retain such workers. The rapid growth of the digital sector has also drawn skilled personnel away from construction, reducing the industry's available talent pool (Chini, Brown, and Drummond 1999). At the same time, modern construction projects now involve complex designs, advanced materials, green building requirements, and smart home technologies (García de Soto et al. 2019). These developments require stronger digital skills, yet the shortage of competent workers continues to hinder adoption.

Financial constraints also remain a major barrier. Training is necessary for business growth, staff development, and competitiveness, but digital technology training can be costly (Zahra, Iram, and Naeem 2014). These costs include direct training expenses, lost productivity, and administrative burdens, making training a significant challenge for many firms (M. Loosemore and Andonakis 2007). Beyond training, the initial cost of purchasing, installing, maintaining, and upgrading digital systems can also be high. Although digital tools may reduce long-term costs, many firms focus on immediate expenses rather than future benefits. This challenge is especially serious in developing countries, where limited finances, maintenance costs, and inadequate training hinder digitalisation (Emmanuel et al. 2018). Frequent upgrades, large capital requirements, and the need for technical expertise further restrict adoption (El-Mashaleh 2007). Limited financial resources also prevent many organisations from pursuing technology changes altogether (Belle and Dyk 2019).

Connectivity costs and data security concerns create additional difficulties. The internet has transformed computing, communication, and information exchange, building on earlier innovations such as the telegraph, telephone, radio, and computer (Leiner et al. 2009; Bridges 1997). Since most digital risk management tools depend on reliable internet access, high

connectivity costs in developing regions can restrict their use (Petrazzini and Kibati 1999). At the same time, digital tools generate and store large volumes of sensitive project data. This includes designs, blueprints, intellectual property, and trade secrets. As digital footprints increase, privacy and data control become more difficult (Zhang 2018). Construction information may also extend beyond the project environment, creating further risks to confidentiality and intellectual property protection (García de Soto et al. 2020). The Internet of Things increases these risks by connecting people, devices, and systems across different networks, creating opportunities for data theft, resale, and fraud (Gou et al. 2013).

Finally, the limitations of digital tools can reduce confidence in their use. Many construction defects occur during the building process and often result in costly rework and poor building performance (Gordon et al. 2003). Digital risk management tools are intended to detect such defects early and reduce financial losses. However, these tools may also have technical weaknesses. For example, mobile applications used for site data collection may unexpectedly go offline, while RFID tags may be damaged by site conditions or chemical exposure (Borhani 2016). These practical limitations can undermine trust in digital systems and slow their wider adoption in construction.

Methods

This study adopted a quantitative approach to examine how digital technology supports the management of construction hazards. Quantitative methods involve the collection of numerical data and the application of statistical analysis to explain observed phenomena (Apuke 2017). This approach enabled an objective assessment of both the effectiveness and the use of digital tools in construction risk management. The target population comprised construction professionals working in Gauteng, South Africa, regardless of whether they were registered with a professional body. These professionals included quantity surveyors, project managers, engineers, architects, and health and safety inspectors.

Participants were selected through a combination of random sampling and convenience sampling. Random sampling promoted fairness and reduced the likelihood of

bias, while convenience sampling facilitated access to professionals based on their availability and proximity. A total of one hundred questionnaires were distributed, of which eighty-two valid responses were received. The primary data collection instrument was a structured, closed-ended questionnaire administered in English, consisting of two sections. The first section captured demographic information about respondents. The second section explored the barriers to adopting digital technology for risk management in construction. Data collection was conducted both online and in person. The survey was disseminated through professional directories to construction professionals. The internal consistency of the questionnaire scales was evaluated using Cronbach's Alpha to ensure validity and reliability, with an acceptable threshold set at 0.800.

Results and discussion

The respondent profile shows that the study captured a diverse and credible sample of construction industry professionals. In terms of education, 18.29% of respondents had a post-metric certificate or diploma, while 37.80% held a bachelor's degree. Lastly, 43.9% held a post-bachelor's degree. The respondents also represented a wide range of professional roles in the construction sector. Quantity surveyors formed the largest group at 35.37%. Other participants included civil engineers and construction project managers at 10.98% each; construction managers at 9.76%; architects and health and safety officers at 8.54% each; site engineers at 7.32%; industrial engineers at 1.22%; and other construction-related professionals, mainly educators, at 7.32%. Experience levels were also varied. About 35.37% had 0–5 years of experience, 26.83% had 5–10 years, another 26.83% had 10–15 years, 7.32% had 15–20 years, and 3.66% had over 20 years of experience. Respondents were drawn from consulting firms, contracting firms, government bodies, and educational institutions. Overall, the sample was broad, current, and well-positioned to provide reliable insights into construction risk management. The respondent profile confirms that the sample is credible and diverse. Participants had varied qualifications, professional roles, experience levels, and

organisational backgrounds. Their representation across consulting, contracting, government, and educational institutions strengthens the study's validity and ensures that the findings reflect broad, current, and practical perspectives within the construction industry.

Results from descriptive statistics

Using a five-point Likert scale, respondents indicated the extent to which various factors affect the implementation of digital technologies for risk management in construction. The rankings are presented in [table 1](#). The top five barriers identified were lack of top management and leadership support, cost of initial installation

of digital technologies, impact on job opportunities, company resistance to change, and cost of training staff. These findings align closely with [King'oo \(2017\)](#), who argues that leadership backing is the single most important factor for successful organisational change and high-quality service delivery. Without active support from senior managers, expressed through funding, resource allocation, and clear communication, new technologies struggle to gain meaningful traction. [Emmanuel et al. \(2018\)](#) similarly highlight the financial burden of digital adoption, alongside ongoing maintenance expenses and inadequate training, as key obstacles, particularly in developing countries.

Table 1. Inhibitors of digital risk management progress in construction

Drawbacks	$\bar{x}$	σX	R
Lack of top management and leadership support	4.26	0.703	1
Cost of initial installation of digital technologies	4.22	0.917	2
Impact on job opportunities	4.20	0.697	3
Company resistance to change	4.18	0.788	4
Cost of training staff	4.17	0.843	5
Lack of skilled workers	4.04	0.922	6
Insufficient awareness of the benefits of digital technologies	4.03	0.729	7
Company culture	4.00	0.851	8
Lack of awareness and knowledge about digital technologies	3.83	1.163	9
Technology feature defaults/limitations	3.77	0.826	10
Concerns of returned revenue	3.76	0.794	11
Fear of cyber attack	3.64	0.997	12
Fear of data security	3.52	1.091	13
Expensive internet service	3.15	1.286	14

$\bar{x}$ = Mean item score; σX = Standard deviation; R = Rank

These findings suggest that the most pressing obstacles are not purely technological in nature. Rather, they are rooted in organisational leadership, financial constraints, and human factors. The prominence of job loss concerns further reflects the workforce's anxiety about being displaced by automation and digital systems. The remaining barriers, while ranked lower, are nonetheless noteworthy. Lack of skilled workers, insufficient awareness of the benefits of digital technologies, and company culture featured prominently in the mid-rankings, pointing to a broader skills and knowledge gap within the industry. Expensive internet service ranked last, suggesting that connectivity costs, while a concern, are perceived as a lesser obstacle relative to the organisational and financial challenges ranked above it. Overall, the results indicate that successfully implementing digital technologies for risk management in construction demands more than investment in tools and infrastructure. It requires strong leadership

commitment, cultural change, workforce development, and deliberate strategies to manage the human dimensions of digital transition.

Results from exploratory factor analysis

Prior to executing Principal Component Analysis (PCA), the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's Test of Sphericity were administered to evaluate the data's appropriateness for factor analysis, as illustrated in [table 2](#). All 14 measured variables underwent PCA with a Varimax rotation to discern clusters of latent factors. The KMO test yielded a value of 0.628, surpassing the minimum criterion of 0.6 established by [Yong and Pearce \(2013\)](#), signifying that the sample is suitable for factor analysis. Likewise, Bartlett's Test of Sphericity produced a Chi-Square value of 444.600, with a significance level of $p = 0.000$, which is below 0.05. These results validate the existence of sufficient correlations among variables, hence substantiating the use of PCA.

The communalities indicate that all items had initial of 1.000, which is consistent with the use of PCA. This suggests that the total variance in each variable was considered, and all items were fully included in the factor extraction process.

Table 2. KMO and Bartlett's test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy	0.628
Bartlett's Test of Sphericity	Approx. Chi-Square
	df
	Sig.
	444.600
	91
	0.000

Using the Principal Component Analysis and following Kaiser's criterion of retaining components with eigenvalues greater than 1.0, four components were extracted with eigenvalues of 4.204, 2.560, 1.304, and 1.299, respectively. These four factors cumulatively account for 66.773% of the total variance across the 14 measured variables, with the first three factors explaining 30.026%, 18.288%, 9.314%, and 9.145 of the variance, respectively. As revealed in table 3, the factor analysis yielded four distinct components, each capturing a different dimension of the barriers to implementing digital technologies for risk management in construction.

Table 3. Extracted rotated component matrix

Drawbacks	Component			
	1	2	3	4
Expensive internet service	0.890			
Fear of data security	0.811			
Fear of cyber attack	0.713			
Technology feature defaults/limitations	0.588			
Cost of initial installation of digital technologies		0.856		
Cost of training staff		0.726		
Lack of skilled workers		0.681		
Lack of top management and leadership support		0.651		
Impact on job opportunities			0.811	
Concerns of returned revenue			0.689	
Insufficient awareness on the benefits of digital technologies			0.602	
Lack of awareness and knowledge about digital technologies				0.860
Company resistance to change				0.794

2. Financial and human resource constraints: The second factor grouped the cost of initial installation (0.856), cost of training staff (0.726), lack of skilled workers (0.681), and lack of top management and leadership support (0.651), capturing the financial and human resource constraints that limit digital uptake from within organisations. Emmanuel et al. (2018) and Zahra, Iram, and Naeem (2014) find that the costs of acquiring and maintaining digital tools weigh particularly heavily on small and medium-sized

1. Technological and infrastructural constraints: The first factor, accounting for the largest share of explained variance, grouped expensive internet service (0.890), fear of data security (0.811), fear of cyber-attack (0.713), and technology feature defaults and limitations (0.588). This reflects the technological and infrastructural constraints that make construction professionals wary of digital adoption, particularly in developing regions where connectivity is costly and data protection frameworks are less robust. This grouping reveals that many construction firms face serious infrastructure limitations. High internet costs and concerns about cyberattacks actively discourage digital uptake. Petrazzini and Kibati (1999) note that while internet access is expanding globally, costs remain prohibitive in many developing regions. Zhang (2018) and García de Soto et al. (2020) further stress that fears around data security erode trust in digital systems. Technical vulnerabilities, such as RFID tag failures reported by Borhani (2016) and software downtime documented by Gordon et al. (2003), compound this reluctance and undermine confidence in the reliability of digital tools.

firms. M. Loosemore and Andonakis (2007) confirm that training is often deprioritised when budgets are under pressure. García de Soto et al. (2020) and Ganesh and Tyagi (2021) further underscore how persistent skills gaps stall innovation and slow the pace of adoption. King'oo (2017) and Rodríguez, Pérez, and Gutiérrez (2008) reinforce the critical need for strong leadership to champion and sustain digital change initiatives from the top down.

3. Economic uncertainty and workforce constraints: The third factor brought together the impact on job opportunities (0.811), concerns about returned revenue (0.689), and insufficient awareness of the benefits of digital technologies (0.602), reflecting the economic uncertainty and workforce constraints that accompany digital transformation. This component groups together fear of job displacement, uncertainty about financial returns, and low awareness of the benefits of digital technologies. These variables reflect the broader anxieties that accompany digital transformation in the sector. Stakeholders worry that automation will displace workers without delivering clear or measurable gains in return. [Chini, Brown, and Drummond \(1999\)](#) link such fears to entrenched negative perceptions of technology, which, left unaddressed, create lasting resistance to adoption.

4. Knowledge gaps and cultural constraints: The fourth factor grouped lack of awareness and knowledge about digital technologies (0.860) with company resistance to change (0.794), highlighting how knowledge gaps and cultural constraints reinforce one another to create deeply entrenched organisational barriers. This grouping highlights how deeply rooted cultural and information deficits compound to create significant barriers. [Morcos \(2018\)](#) demonstrates how organisational culture fundamentally shapes a firm's openness to new ideas and ways of working. [Lojda et al. \(2020\)](#) and [Mitchell and Demian \(2011\)](#) find that teams tend to cling to familiar practices, making the rollout of new digital systems considerably more difficult in environments where a culture of innovation has not yet been established.

In finality, these findings carry important implications for the industry. They demonstrate that any meaningful push towards digital risk management in construction must address infrastructure deficiencies, financial constraints, skills development, economic anxieties, and cultural resistance in a coordinated and deliberate manner. Technology alone cannot drive adoption. It must be accompanied by strong leadership, adequate investment, and a sustained commitment to building the capacity and confidence of the workforce.

Implications of findings

Lack of top management and leadership support, together with inadequate investment in staff training and equipment, continues to hinder the adoption of digital technologies in the

Nigerian construction industry. This resistance is largely driven by the high initial implementation cost. Although digital tools can reduce project risks and lower costs over time, many firms focus on immediate expenses rather than long-term savings. As a result, important benefits such as improved productivity, enhanced safety, better risk mitigation, and data-driven decision-making are often overlooked. This short-term view is further reinforced by the construction industry's conservative culture, which is often resistant to rapid change and innovation. The study also identified broader economic and labour market concerns. Some workers fear that digital adoption may lead to job losses, while many stakeholders still lack a clear understanding of the benefits of digital transformation. This knowledge gap fuels social resistance and hesitation across different levels of the industry.

To address these concerns, the sector requires targeted awareness campaigns, educational initiatives, and inclusive communication strategies. These efforts should demonstrate how digital technologies can support, rather than replace, human labour. Infrastructural barriers, including expensive internet services and cybersecurity concerns, also highlight the need for improved digital infrastructure and stronger regulatory frameworks. Without reliable and secure connectivity, even well-designed digital strategies may fail. Achieving meaningful change, therefore, requires a multi-level approach. Industry leaders must show commitment and allocate sufficient resources. The workforce must receive adequate training, infrastructure must be improved, and organisations must develop cultures that support innovation. Public and private stakeholders must also collaborate to create an enabling environment for digital transformation. Without such coordinated action, the construction industry may miss the opportunity to achieve greater efficiency, accuracy, safety, and global competitiveness through digital technologies.

Conclusions

This study examined the barriers to the adoption of digital technologies for risk management in the South African construction industry. Although these tools can improve efficiency, safety, accuracy, productivity, communication, and

decision-making, their uptake remains low. The main barriers identified include data security concerns, high internet costs, financial constraints, workforce limitations, economic and labour market challenges, and organisational and cultural resistance. The findings show that digital adoption is not only a technical issue. It also depends on leadership support, staff competence, organisational readiness, and change management. Construction firms should therefore involve senior leaders in digital strategies and ensure that management provides clear direction, adequate resources, and continuous staff training. Firms should also create a culture that supports gradual change, innovation, and learning. In addition, awareness programmes should be introduced to demonstrate the long-term value of digital tools in reducing risks and improving project performance. Future research should explore industry-specific case studies, behavioural resistance, leadership dynamics, and change management strategies. Further studies could also examine how firm size, ownership structure, and project type affect digital readiness and successful implementation.

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Olushola Akinshipe contributed to the research concepts preparation, methodologies, investigations, data analysis, visualization, articles drafting and revisions.

Clinton Aigbavboa contribute to the research concepts preparation and literature reviews, data analysis, of article drafts preparation and validation.