

THE ROLE OF ARTIFICIAL INTELLIGENCE IN KEY PROJECT MANAGEMENT FUNCTIONS

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Abstract

The integration of Artificial Intelligence (AI) into construction project management is reshaping how projects are planned, executed, and controlled, particularly in the context of the Fourth Industrial Revolution (4IR). This study explores the influence of AI on key project management functions, namely cost management, schedule control, and decision-making within the South African construction industry. A qualitative desktop research approach was employed, relying on a systematic review of peer-reviewed journal articles, industry reports, and policy documents published between 2017 and 2025. Thematic analysis was used to synthesise and interpret the literature. The results indicate that AI technologies such as machine learning, predictive analytics, computer vision, and BIM-integrated systems significantly improve project cost estimation, financial monitoring, and resource allocation. In scheduling, AI enhances planning accuracy by enabling real-time progress tracking, predictive delay identification, and adaptive rescheduling through data captured from digital tools such as drones and sensors. Furthermore, AI strengthens decision-making and risk management by providing data-driven insights, early warning systems, and scenario-based forecasting, thereby reducing uncertainty and improving project control. However, the study also highlights that AI adoption in South Africa remains in an emerging stage and is not yet widely implemented across the construction sector. Challenges such as limited digital infrastructure, high implementation costs, fragmented project data, shortage of skilled professionals, and resistance to technological change continue to hinder widespread adoption, particularly among small and medium-sized enterprises. The study concludes that AI has the potential to significantly enhance construction project performance by improving efficiency, accuracy, and risk responsiveness. To fully realise these benefits, the South African construction industry must prioritise digital transformation through investment in technology, skills development, and supportive institutional frameworks that encourage innovation and integration of AI-driven systems.

Keywords: Artificial Intelligence, Building Information Modelling (BIM), Construction Project Management, Digital Transformation, South Africa.

1. INTRODUCTION

The construction industry is a key driver of economic development, infrastructure delivery, and employment creation globally; however, it continues to face persistent challenges such as cost overruns, project delays, safety incidents, and low productivity (Oesterreich & Teuteberg, 2016). These challenges are often linked to fragmented information flows, reliance on manual processes, and limited data-driven decision-making within traditional construction project management systems. In response, the industry is undergoing a significant transformation driven by digital technologies associated with the Fourth Industrial Revolution (4IR), with Artificial Intelligence (AI) emerging as one of the most influential innovations. AI refers to computational systems capable of performing tasks that typically require human intelligence, including learning, reasoning, prediction, and decision-making (Russell & Norvig, 2021). In construction project management, AI technologies such as machine learning, computer vision, natural language processing, and predictive analytics are increasingly being used to improve

planning accuracy, automate repetitive processes, and enhance decision-making efficiency (Zhang & El-Gohary, 2021). These technologies are reshaping how project data is collected, analysed, and applied across all phases of the construction lifecycle. Globally, AI adoption in construction is gaining momentum, particularly in developed economies where digital transformation strategies are well established. Countries such as China, the United States, and the United Kingdom are actively integrating AI into cost estimation, risk analysis, scheduling optimisation, and quality control systems (Elhegazy et al., 2022). The integration of AI with Building Information Modelling (BIM) and Internet of Things (IoT) technologies has further enhanced real-time monitoring, predictive maintenance, and intelligent project planning capabilities (Du et al., 2021). These advancements contribute to improved productivity, reduced errors, and more efficient resource utilisation in construction projects (Li et al., 2023). Despite these global developments, the South African construction industry is still in the early stages of AI adoption. The sector is characterised by a strong reliance on labour-intensive methods, uneven digital maturity, and limited technological infrastructure across firms (CIDB, 2022). While large contractors and multinational firms have begun implementing AI-enabled systems for scheduling, cost forecasting, and safety monitoring, small and medium-sized enterprises (SMEs) continue to lag due to financial constraints, limited technical expertise, and resistance to organisational change (Tjebane et al., 2022).

Nevertheless, there is growing recognition of the potential benefits of AI within the South African built environment. Increasing adoption of BIM, cloud computing, and data analytics is gradually creating a foundation for AI integration in construction project management practices (Moyo et al., 2023). Government-led digital transformation initiatives and innovation strategies further signal a shift towards embracing advanced technologies in the construction sector (DTIC, 2023). However, empirical studies remain limited regarding the actual extent of AI implementation, readiness levels, and practical challenges within the South African context. Therefore, this study examines the impact of Artificial Intelligence on key construction project management functions, with a specific focus on cost management, scheduling, and decision-making processes. It also explores the current level of AI adoption in South Africa, identifies barriers to implementation, and highlights opportunities for improving construction project performance through AI-driven technologies.

2. LITERATURE REVIEW

2.1 AI enhances cost management & financial control

The quick estimation of engineering quantities and project costs is a major benefit of AI. Traditional methods that depend on list prices or quota measurements are often labour-intensive, time-consuming, and heavily rely on human experience, which reduces their efficiency and reliability. AI models allow for faster and more accurate cost estimation by using historical project data and pattern recognition. By leveraging AI, project managers can detect early signs of cost overruns and identify cost-saving opportunities by analysing historical project data, financial reports, and real-time project progress information. This predictive capability mitigates the risks of unanticipated expenses and schedule delays, which are

common causes of budget escalations in South African construction projects (Al-Hazim et al., 2017). Although initial AI implementation involves substantial capital investments, the long-term financial benefits through improved cost control, reduced overruns, and increased project delivery success make AI a valuable asset, especially for the developing South African construction sector striving for competitiveness on a global scale (Makaula et al., 2021b). AI plays a crucial role in managing costs and finances in construction projects by enabling faster and more precise estimation, budgeting, and expense tracking. Combining AI algorithms with traditional project cost management systems and BIM tools helps estimators produce more accurate cost estimates in less time. AI tools also help automate financial processes, identify transaction irregularities, and improve resource allocation through predictive analytics. Innovations in AI-driven cost control extend throughout all project stages, from feasibility studies to bidding, design, construction, and post-completion evaluations. These systems help manage information redundancies by centralizing project data, enhancing communication among stakeholders, and fostering transparency in financial reporting. Consequently, AI and BIM collaboration enhance the integrity of cost-related information and facilitate comprehensive financial control in construction projects (Zhang et al., 2021). In the context of South Africa, where construction margins are often tight and financial mismanagement can compromise project success, AI's role in enhancing cost control translates into improved profitability and risk reduction. Through better forecast models and data-driven financial oversight, AI empowers stakeholders to maintain budget discipline and respond swiftly to cost deviations, thereby strengthening project financial management practices critical for the region's construction sector stability and growth. Though acceptance is patchy, South African construction companies are aware of AI's potential. While many still use manual methods, some, usually larger private sector companies, have begun utilizing AI and automation techniques (Mgolombane, 2023).

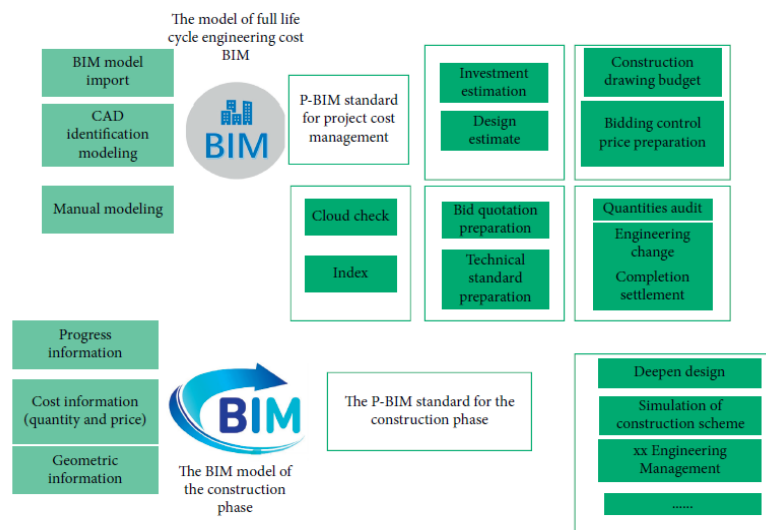


Figure 1: Model of Full Lifecycle Engineering Cost

Source: Mgolombane, 2023

A) AI substantially improves early-stage cost estimation accuracy and speed

Several systematic and empirical studies demonstrate that supervised machine learning models (such as random forests, gradient boosting, and neural networks) surpass traditional statistical or expert-rule approaches for conceptual and preliminary cost estimations, decreasing mean error and facilitating expedited quotation and bidding cycles (Hashfi and Raharjo, 2023b). Representative evidence: comparative studies and reviews report that ensemble tree models and gradient boosting often provide the best trade-off between accuracy and interpretability for cost prediction tasks; deep learning excels when large, rich datasets (e.g., historical BIM/BOQ data) are available. (Rudge, 2024)

B) AI supports automated document processing and BOQ classification lowers labour and error rates

Bills of quantities, contracts, and invoices are processed using document-classification techniques and Natural Language Processing (NLP). The findings demonstrate that automation lowers the workload associated with manual classification while identifying unusual claims or invoice issues. This minimizes payment delays and speeds up verification (Hashfi and Raharjo, 2023b).

C) AI for cost control, cash-flow forecasting and risk/uncertainty quantification

Managers can identify cost overruns and cash-flow deficits earlier than they could with traditional variance reporting when they combine machine learning (ML) models with probabilistic techniques and uncertainty quantification (e.g., Monte Carlo, Bayesian approaches, prediction intervals). Recent SLRs claim that AI techniques are being applied to provide probabilistic forecasts and risk assessments that feed control dashboards at the project level (Hashfi and Raharjo, 2023a).

D) Proven/claimed benefits

More accurate early estimates and updated forecasts: ML models improve budget realism and lessen surprises by reducing estimation error when historical data is sufficient (Makaula et al., 2021b).

- Quicker cost variance detection: Integrated data pipelines and real-time monitoring allow for the early identification of negative trends, allowing for remedial action to be taken early in the project lifecycle. (Makaula and others, 2021).
- Automating repetitive financial duties: Automated quantity take-offs, remeasurements, and invoice checks improve auditability and cash flow control by reducing administrative time and human error. (Makaula and others, 2021).

E) South African evidence and contextual findings

- **Capital & procurement constraints:** Small and medium contractors face capital barriers to adopt integrated AI/BIM stacks even where benefits are clear. Public-sector procurement rigidity can also restrict innovative contracting that aligns with AI-driven workflows (Makaula et al., 2021b).

- **Fragmented supply chains & informal markets:** Where material sourcing and subcontracting are informal, traceable data needed for predictive cost models are often missing (Makaula et al., 2021b).

F) Limitations, practical barriers and critical caveats

Due to strict procurement and capital requirements, small and medium-sized contractors encounter financial obstacles when attempting to implement integrated AI/BIM stacks, even in cases where the advantages are evident. Rigidity in public sector procurement may also impede creative contracting that complements AI-driven processes (Makaula et al., 2021b). Fragmented supply chains and informal markets: Traceable data required for predictive cost models is frequently absent in situations where material sourcing and subcontracting are informal (Makaula et al., 2021b).

2.3.2 Schedule and Time Management

AI scheduling techniques include heuristics/optimization for re-sequencing under uncertainty, reinforcement learning for resource allocation, and sequence-prediction machine learning models. Integration with BIM and real-time progress capture (drones, IoT sensors) enable dynamic schedule updating and near-real-time critical path analysis (Makaula et al., 2021). Scheduling is another area where AI has shown significant promise in enhancing productivity and predictability. Machine learning algorithms, especially reinforcement learning and neural networks, can analyse historical project data to forecast potential delays and resource limitations (Zhang et al., 2021). By using drones and sensors to track on-site progress, the combination of AI and BIM enables automatic timetable tracking that reduces manual reporting errors (Makaula et al., 2021b). Computer vision tools that process images in real time can identify deviations from expected development and take corrective action more quickly.

Benefits

AI-assisted scheduling has been shown to improve time estimation accuracy and reduce project duration by up to 20% worldwide through early delay identification (Darko, Chan & Ameyaw, 2020). Predictive scheduling software and AI-integrated construction monitoring platforms are gradually achieving these benefits in South African infrastructure projects (CIDB, 2022).

South Africa's challenges

The largest barriers to AI scheduling solutions in South Africa are data fragmentation and a dearth of standardized progress monitoring systems (Makaula et al., 2021). Since many businesses still rely on manual updates, there is a limited amount of data available for training predictive algorithms. Connectivity problems at distant project sites also restrict the real-time deployment of AI systems.

Algorithmic scheduling is also culturally disliked by project managers, who may prefer more traditional software such as Microsoft Project or Primavera. Interpretability and human oversight remain crucial for fostering confidence in AI-generated outputs (Olatunji & Aghimien, 2023). By facilitating adaptive rescheduling and early risk identification related to time, artificial intelligence (AI) holds the potential to completely transform project scheduling.

To progress from isolated experiments to sector-wide adoption, South Africa has to invest in digital infrastructure, data governance, and training.

3. RESEARCH METHODOLOGY

This study adopted a qualitative research approach using a desktop-based systematic literature review to investigate the impact of Artificial Intelligence on construction project management. Secondary data was collected from peer-reviewed journal articles, conference proceedings, and industry reports published between 2017 and 2025, sourced from academic databases such as Scopus, ScienceDirect, Google Scholar, and Semantic Scholar. The selected literature was analysed using thematic content analysis to identify recurring themes related to AI applications in cost management, scheduling, decision-making, and risk management in construction. This approach enabled the synthesis of existing knowledge while ensuring a comprehensive understanding of AI adoption trends, benefits, and challenges within the South African construction industry (Snyder, 2019; Braun & Clarke, 2019).

4. FINDINGS AND DISCUSSION

4.4 Challenges and Barriers to AI Implementation in South Africa

4.4.1 Low Levels of Digitisation and Legacy Systems

One of the most significant hurdles highlighted is the low level of digitalization in South Africa's building industry. The sector still relies on legacy systems and human data management practices that are incompatible with AI technology (Makaula et al., 2021b). The lack of integrated digital platforms, such as Building Information Modelling (BIM), digital twins, and cloud-based project data systems, reduces the availability of structured, machine-readable data required for effective AI deployment (Oesterreich & Teuteberg, 2016; Dave et al., 2021).

4.4.2 High Upfront Costs and Uncertain Return on Investment

AI implementation necessitates significant financial investment in hardware, software, data infrastructure, and personnel training (Mgolombane, 2023). Many South African businesses work under tight economic constraints, and the uncertainty surrounding return on investment (ROI) is a significant barrier to adoption. According to respondents in Mgolombane's (2024) poll, the major impediments are cost concerns such as purchasing, installation, maintenance, and training. These findings are consistent with worldwide literature, which has identified capital intensity as a universal obstacle to AI adoption in construction (Li et al., 2019).

4.4.3 Skills Shortages and Limited AI Competence

A common topic is a lack of competent people capable of building, implementing, and sustaining AI systems. Construction managers and engineers frequently lack the technical competence required to evaluate and efficiently use AI outputs (Makaula et al., 2021). Similarly, organizational leadership is sometimes unprepared to incorporate digital transformation initiatives into traditional operations (Mgolombane, 2023). The absence of AI

literacy among management teams limits strategic decision-making and innovation uptake (Sawhney et al., 2020).

4.4.4 Cultural Resistance and Industry Conservatism

The construction sector is marked by significant conservatism and reluctance to adapt (Makaula et al., 2021). Many project managers and site people prefer traditional manual procedures, seeing AI technologies as too difficult or disruptive. Resistance to change is exacerbated by inadequate communication of AI's benefits and organizational inertia (Eadie et al., 2013).

4.4.5 Employment Displacement and Socio-Economic Concerns

Concerns about job displacement due to automation represent a distinct sociopolitical hurdle in South Africa, where unemployment remains high. Workers frequently believe that AI and robotics will render their skills obsolete, leading to union resistance and public distrust (Mgolombane, 2024). These concerns underscore the need for inclusive technology policies that prioritise retraining and skill development over job loss (Abioye et al., 2021).

5. CONCLUSION AND FURTHER RESEARCH

The review indicates that the adoption of Artificial Intelligence in construction project management practices within South Africa is gradually increasing, although implementation remains at an early stage compared to developed countries. The findings reveal that AI technologies such as machine learning, predictive analytics, computer vision, and Building Information Modelling (BIM) integration have significant potential to improve project planning, cost estimation, safety management, resource optimization, and decision-making processes in the construction industry. However, AI adoption is currently concentrated among large construction firms and multinational companies, while small and medium-sized enterprises continue to face challenges related to limited financial resources, inadequate digital infrastructure, shortage of skilled personnel, and resistance to technological change. The study further established that organizational readiness, leadership commitment, and digital maturity are critical factors influencing successful AI implementation in construction project management practices.

Despite the identified barriers, the study highlights that the increasing advancement of digital technologies, growing awareness of AI benefits, and ongoing innovation initiatives present significant opportunities for the future integration of AI within the South African construction sector. The review therefore concludes that AI has the potential to transform construction project management by enhancing productivity, improving safety performance, reducing project delays, and supporting data-driven decision-making. However, achieving these benefits will require greater investment in digital infrastructure, professional training, supportive policy frameworks, and industry-wide collaboration. Further research is recommended to conduct empirical investigations into the practical implementation of AI technologies within South African construction projects, particularly among SMEs. Future studies should also explore the relationship between AI adoption and construction project performance, investigate AI

readiness assessment models, and examine the ethical, regulatory, and workforce implications associated with AI-driven construction practices.

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