

Digital Transformation of Construction and Project Management through Artificial Intelligence

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Abstract

Artificial intelligence (AI) is increasingly recognised as a transformative force in construction and project management, thereby automating tasks traditionally dependent on human intelligence. It has emerged as a game-changing tool, enhancing operational efficiency, proactively managing risks, and improving project outcomes. This study explored the application of AI in the construction industry and its associated benefits using systematic literature review approach. Despite these advantages, the industry faces significant challenges integrating AI with existing construction and project management systems. The study analysed approximately 75 relevant articles using a systematic literature review approach. Based on the findings, a comprehensive AI implementation strategy was developed to maximise its benefits while addressing potential risks and challenges.

Keywords: Application, Challenges, Construction, Implementation, Strategy

1. Introduction

The construction and project management sectors, traditionally characterised by labour-intensive processes and fragmented workflows, are undergoing a profound transformation driven by advancements in digital technologies. Among these technologies, artificial intelligence (AI) has emerged as a pivotal force, reshaping how projects are planned, executed, and monitored (Lu et al., 2024). By leveraging AI, stakeholders can enhance efficiency, reduce costs, and mitigate risks, thereby addressing long-standing challenges in the industry. AI is reshaping every stage of the construction project lifecycle, from smart design software that optimises architectural plans to predictive maintenance systems that anticipate equipment failures (Baduge et al., 2022).

Integrating AI into Building Information Modelling (BIM) exemplifies its transformative potential. It enhances BIM by automating design optimisation, clash detection, and resource allocation, streamlining stakeholder collaboration and ensuring better project outcomes (Timilsena et al., 2024). This transformation is about adopting new technologies and fostering a culture of innovation, collaboration, and adaptability. By embracing AI, the construction and project management industries are addressing long-standing challenges such as delays, cost overruns, and resource inefficiencies and paving the way for sustainable and resilient infrastructure development (Shamim, 2024).

Despite its benefits, the adoption of AI in construction and project management faces challenges, including resistance to change, data privacy concerns, and the need for skilled personnel to operate advanced systems (Shoushtari et al., 2024). Addressing these barriers is

critical to unlocking the full potential of AI and fostering a culture of innovation in the industry.

This study outlines the foundational principles and key components of designing an AI implementation strategy for construction and project management. By grounding the discussion in scholarly research and industry best practices, it provides a comprehensive framework for stakeholders seeking to harness the transformative power of AI in the construction industry.

2. Literature Review

Historically, construction processes were marked by hierarchical systems and rudimentary project management principles, emphasising craftsmanship and manual labour with minimal reliance on formalised planning or scheduling tools. The introduction of computers in the 1990s, as Eastman (2018) noted, revolutionised project management by enabling the adoption of systems theory. This allowed for the integrated management of resources, time, and costs. In the 21st century, advanced digital technologies have further transformed construction and project management. According to Lu et al. (2024), these technologies emphasise sustainable practices and lean construction principles that minimise waste and risk while improving overall efficiency.

Although, the construction industry has been slow to adopt technological innovations, recent advancements in AI are driving significant changes. AI technologies such as machine learning, computer vision, natural language processing, and robotics are increasingly being integrated into construction processes to enhance efficiency, accuracy, and safety (Korke et al., 2023). Akhmedov (2023) and Khan et al. (2024) emphasised that integrating AI technologies into the construction

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and project management industry has been transforming construction processes. They highlighted AI's role in enhancing project efficiency, productivity, accuracy, and decision-making, addressing long-standing challenges such as cost overruns, schedule delays, risk mitigation, and resource mismanagement. However, despite these advantages, the widespread adoption of AI faces significant challenges, including technological, organisational, financial, and cultural barriers. Regona et al. (2022) identified issues such as data quality and availability, platform integration, lack of standardisation, and cybersecurity threats as major obstacles. Oke et al. (2023) pointed to resistance to change, while Shang et al. (2023) highlighted a shortage of professionals skilled in AI and data science. Shakibaei (2024) also noted regulatory compliance and ethical concerns as critical barriers to implementing AI in the construction and project management sector.

These challenges highlight the importance of developing a comprehensive AI implementation strategy that integrates education, policy support, stakeholders and industry collaboration to drive the adoption of AI in construction and project management.

3. Research Methodology

The study employs a systematic literature review methodology, adhering to a structured research approach to ensure a rigorous and transparent analysis of existing literature. Review research involves the application of scientific methods to analyse and synthesise previous studies, thereby generating new knowledge for academic, practical, and policy-making purposes (Kunisch *et al.*, 2023). The primary motivation for reviewing and analysing academic articles is to identify research gaps, explore under-researched areas, and facilitate the development of new theories or ideas (Marzi *et al.*, 2024).

This research study review follows a series of steps to achieve the desired outcome. In the initial phase, a comprehensive keyword search was conducted across leading academic databases, such as Scopus, Google Scholar, Web of Science, IEEE Xplore, and ResearchGate, using terms like Artificial Intelligence in Construction, Construction Industry, Construction Project Management, Construction Automation, Construction Design, and Predictive Analytics in Construction. The search produced a total of 458 articles.

The inclusion and exclusion criteria were defined to maintain a clear focus on the research area. Studies were included if they met the following criteria: they examined the impact of artificial intelligence in construction and project management; were published in peer-reviewed journals, academic conferences, or reputable research reports; were written in English; and

specifically addressed aspects of construction and project management. Conversely, studies were excluded if they were purely theoretical or conceptual without empirical evidence on the adoption of artificial intelligence in construction and project management or if they focused broadly on digital technologies rather than artificial intelligence specifically.

A thorough screening process was then carried out following the defined inclusion and exclusion criteria to guarantee relevance and quality. Duplicate entries and articles unrelated to the construction industry or without AI applications were removed, yielding a final selection of 75 articles. Furthermore, a strong focus was placed on articles published between 2018 and 2024 to capture the latest trends and advancements, this narrowed the selection to 28 articles.

The study progressed to a comprehensive thematic analysis phase, aiming to clarify the current status, limitations, and future trends of AI applications in construction and project management. The focus was primarily on key findings and conclusions from the reviewed articles, specific challenges and opportunities identified, and recommendations for policy, practice, and further research. Ultimately, 24 articles were finally cited in this study.

4. Findings and Discussion

4.1. Application of Artificial Intelligence in Construction and Project Management

The integration of artificial intelligence (AI) into construction and project management involves exploiting advanced technologies to improve efficiency, accuracy, and decision-making, thereby addressing the inherent challenges in the industry, such as cost overruns, schedule delays, risk mitigation, and resource mismanagement. According to Akhmedov (2023), AI-driven tools, like generative design software, enable architects and engineers to rapidly explore numerous design alternatives while optimising key factors like cost, sustainability, and structural integrity. Similarly, Baduge *et al.* (2022) posit that AI algorithms leverage historical data to predict project timelines and identify potential risks, forecasting delays and propose corrective actions. These are made possible through the optimisation of project schedules using generative scheduling, resource allocation, and risk assessment.

Yu and Wang (2022), assert that AI-powered systems enable organisations to identify trends, predict potential issues, and make informed decisions based on accurate and up-to-date information. This assertion is corroborated by Khan *et al.* (2024), the authors confirm that the excellent performance of AI systems in analysing real-time data from Internet of Things (IoT) devices, cameras, and sensors, making them highly effective in predicting and preventing accidents on

construction sites. Technologies such as computer vision and AI-driven drones enhance site safety by providing real-time monitoring and ensuring compliance with project specifications (Khan *et al.*, 2024),

Putha (2022) maintains that AI-driven predictive maintenance uses machine learning models and data analytics to process extensive sensor data from equipment, identifying patterns and anomalies indicative of potential failures. According to Qi and Tao (2018), predictive maintenance is an advanced equipment management strategy that employs AI algorithms to analyse real-time data, predict potential failures, and implement preventive measures. It adopts a proactive approach, unlike traditional maintenance methods that rely on scheduled inspections or reactive repairs. In the construction industry, the AI systems utilise condition-based monitoring and predictive analytics techniques to analyse sensor data that enables proactive maintenance, minimise equipment downtime, and enhance the efficiency of construction projects (Shoushtari *et al.*, 2024 and Singh *et al.*, 2023).

Furthermore, Pan and Zhang (2021), submit that adopting AI models in construction and project management has significantly improved the accuracy of risk assessment and management by analysing extensive datasets, such as weather patterns, financial trends, and stakeholders' behaviours. The AI systems have been able to leverage on historical project data and external variables to predict risks like cost overruns, delays, and quality issues (Korke *et al.*, 2023).

Construction projects are inherently complex and multifaceted, demanding effective coordination and streamlined material procurement and logistics management. Okoye *et al.* (2024) maintain that the success of construction projects hinges on the efficiency of the construction supply chain, encompassing the acquisition and movement of materials throughout the project lifecycle. The integration of AI into project management platforms has enhanced inventory tracking, demand forecasting, and procurement processes through smart procurement strategies, ensuring the timely delivery of materials and equipment (Culot *et al.*, 2024). The adoption of AI in construction and project management has thereby led to a more cost effective, efficient, productive, proactive, safe and sustainable construction industry.

4.2. Challenges of Artificial Intelligence Implementation in Construction Industry

Integrating artificial intelligence (AI) into the construction and project management sector holds significant promise for enhancing efficiency, accuracy, and decision-making. Despite this potential, its widespread adoption faces several challenges. These challenges can be broadly classified into four

categories: technological, organisational, financial, and cultural.

According to Regona *et al.* (2022) and Obiuto *et al.* (2024), construction projects often lack standardised data collection processes, leading to inconsistent, incomplete, or siloed data that limit the effectiveness of AI functionalities. Pan & Zhang (2021) argue that the lack of standard data formats and protocols within the construction sector further complicates AI implementation, as AI systems rely heavily on large volumes of accurate and structured data.

Similarly, challenges like resistance to change, leadership commitment, and manpower capability gap are pronounced. Oke *et al.* (2023) argue that many construction professionals hesitate to adopt new technologies due to a lack of familiarity with AI technology or fear of job displacement, while Shang *et al.* (2023) posit that the construction industry faces a shortage of professionals skilled in AI and data science, creating a bottleneck for implementation. Besides, Fasasi *et al.* (2024) noted that the industry's conservativeness and high fragmentation, characterised by numerous small players and subcontractors, complicate collaboration on AI initiatives. More so, the concerns about the transparency of AI decision-making processes further erode trust and acceptance among stakeholders (Pan & Zhang, 2021).

Financial constraints are also identified as a significant challenge in adopting AI systems within the construction and project management sector. Oke *et al.* (2023) highlight the financial and economic hurdles the construction industry faces, particularly the high costs associated with developing and deploying AI solutions, and Korke *et al.* (2023) submit that implementing AI requires substantial initial software, hardware, and skilled personnel investments. These upfront costs can be prohibitive, particularly for smaller construction firms.

AI models face challenges in handling unstructured environments typical of construction sites, and computational demands often constrain their ability to make real-time decisions. These technical limitations diminish AI's effectiveness in dynamic construction settings. Zhang *et al.* (2021) highlight regulatory and ethical barriers like data privacy concerns, algorithmic bias, and accountability for AI-driven decisions as challenges to AI adoption. Similarly, Shakibaei (2024) underscored the necessity for AI systems to adhere to various regulations, which remain inadequately defined for the construction sector. The summarised AI categorised challenges, impact and mitigation strategies in construction sector is presented in Table 1.

Table 1: AI Challenges and Impact in Construction Sector

Category	Challenges	Impact	Mitigation Strategies
Technological	✓ Lack of standardised & quality data ✓ Compatibility with the existing systems ✓ Data & cybersecurity threats	✓ Reduces AI accuracy & reliability ✓ High costs & technical barriers ✓ Loss of sensitive project data	✓ Establish data collection & protocols ✓ Gradual systems upgrades & middleware solutions ✓ Robust cybersecurity measures
Organisational	✓ shortage of professional skills ✓ AI decision-making bias	✓ Slows AI implementation ✓ Social & legal implications	✓ Upskilling training programmes ✓ Design ethical AI guidelines
Financial	✓ High initial investment for AI infrastructure ✓ Skilled personnel investments	✓ Limits adoption by small firms ✓ Slow down AI adoption	✓ Seek government incentives ✓ Adopt phased implementation ✓ Outsource personnel
Cultural/Environmental	✓ Compliance with data & legal standards ✓ AI adaptability to unstructured environments	✓ Delays in AI adoption ✓ Production of Inaccurate AI results and predictions	✓ Collaboration with regulatory bodies ✓ Refinement of the AI model

Korke et al. (2023), Obiuto et al. (2024), Oke et al. (2023), and Shakibaei (2024) underscore the importance of developing a comprehensive artificial intelligence implementation strategy specifically tailored to the construction industry, emphasising that such a strategy is essential for unlocking the full potential benefits that artificial intelligence offers to the construction and project management sectors.

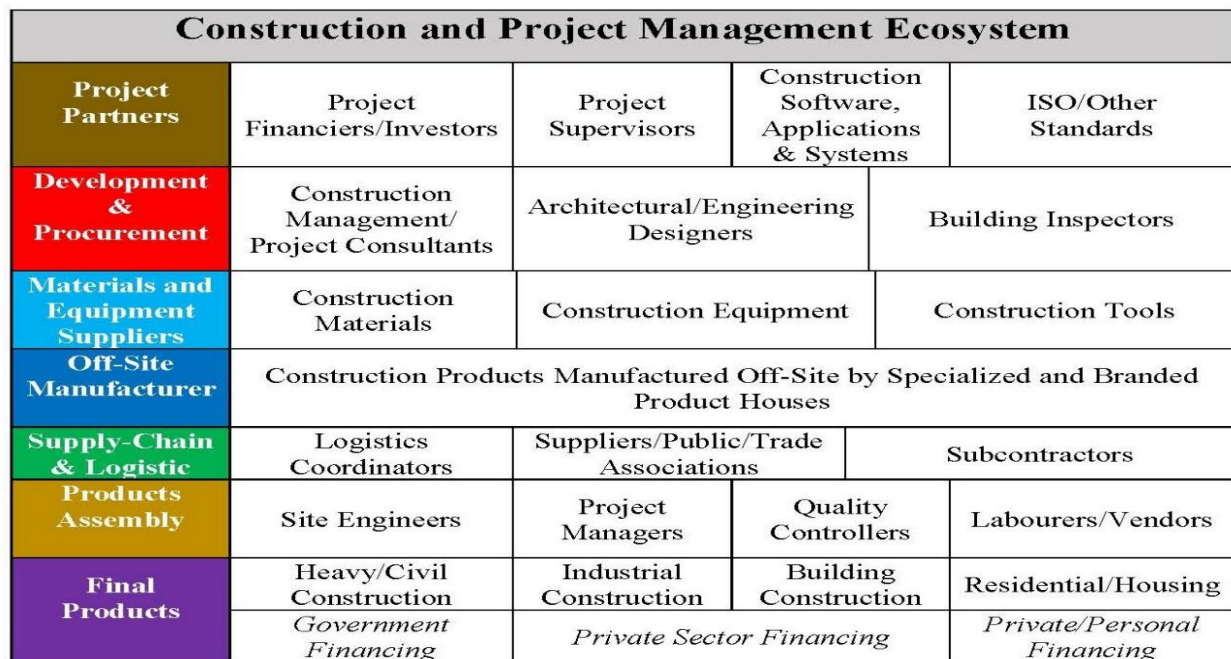
4.3. Recommended Artificial Intelligence Implementation Strategy

At the heart of the digital transformation of the construction and project management sector through artificial intelligence is recognising the inherent complexity and variability characterising construction projects (Lu et al., 2024). From fluctuating material costs and labour availability to unpredictable weather

conditions and regulatory changes, construction projects stakeholders face many challenges that demand precision, adaptability, and foresight.

The construction ecosystem is a complex and dynamic system encompassing various disciplines and stakeholders to ensure that projects are completed on time, within budget, and to the desired quality standards. A conceptualised construction and project management ecosystem is provided in Figure 1. Therefore, implementing artificial intelligence (AI) in this industry requires a well-designed strategy to maximise its benefits while minimising risks and challenges (Obiuto et al., 2024 and Shakibaei, 2024).

This study introduces a comprehensive AI implementation strategy tailored to the construction and project management industry. The conceptual

**Figure 1:** Construction and Project Management Ecosystem

framework for this strategy is illustrated in Figure 2, accompanied by a detailed description of its components.

4.3.1. Assess Needs and Opportunities

- I. **Identify Pain Points:** Evaluation of the areas where AI can provide the most value, such as project scheduling, risk management, resource allocation, quality control, safety monitoring, and predictive maintenance, should be conducted.
- II. **Set Clear Objectives:** Specify goals for AI adoption, like reducing project delays, improving safety compliance, or optimising material usage.

4.3.2. Build Awareness and Buy-In

- I. **Stakeholder Engagement:** The stakeholders within the construction organisation, including project managers, engineers, and site workers, should be engaged and educated about AI's potential benefits and address concerns.
- II. **Leadership Advocacy:** Support from the organisation's senior management should be secured to ensure alignment with organisational goals.

4.3.3. Develop a Pilot Programme

- I. **Start Small:** Choose a manageable project or process to test AI tools, such as machine learning for predictive scheduling or drones for site inspections.
- II. **Define Metrics:** Choose Key Performance Indicators (KPIs) to measure the pilot's success, like cost savings, time efficiency, or error reduction.

4.3.4. Choose the Right AI Tools

- I. **Evaluate Solutions:** Selection of AI technologies suited to the construction industry is required, such as:
 - ✓ **Building Information Modeling:** For design optimisation and clash detection.
 - ✓ **Predictive Analytics:** This is used to anticipate delays and risks.
 - ✓ **Computer Vision:** This is used to monitor site safety and progress.
- II. **Vendor Collaboration:** A partnership with reputable, experienced AI providers in construction and project management should be established.

4.3.5. Build Infrastructure and Skills

- I. **Data Readiness:** Ensure data collection systems have clean, structured data for AI training and analysis.
- II. **Training Programmes:** Upskill employees to use AI tools effectively and understand their outputs.
- III. **Integration with Existing Systems:** Seamlessly connect AI tools with existing construction and project management software and workflows.

4.3.6. Scale and Optimise

- i. **Analyse Pilot Results:** Use insights from the pilot to refine AI applications and address challenges.
- ii. **Expand Adoption:** Gradually implement AI solutions across more projects.

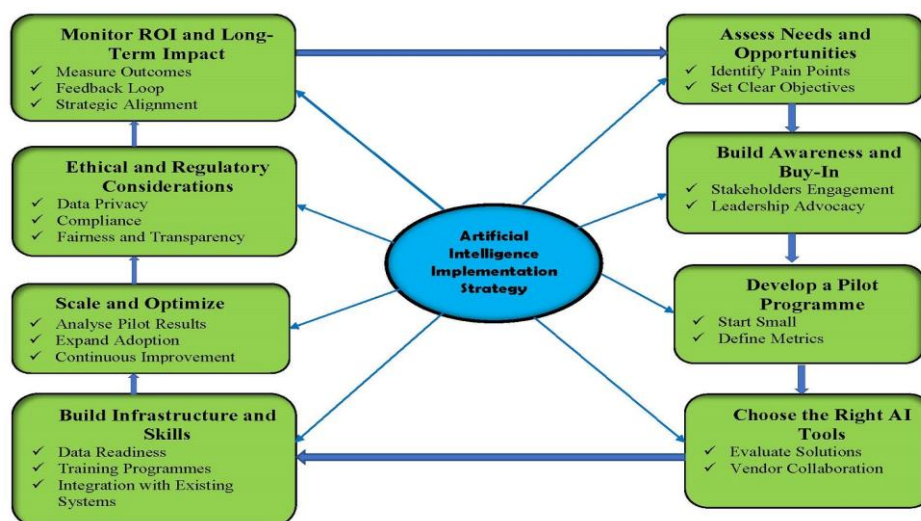


Figure 2: Conceptual Diagram of Artificial Intelligence Implementation Strategy

- iii. **Continuous Improvement:** Monitor AI performance, update algorithms, and adapt to changing project requirements.
- 4.3.7. Address Ethical and Regulatory Considerations**
- i. **Data Privacy:** Implement measures to secure sensitive project and worker data.
 - ii. **Compliance:** Ensure AI tools comply with construction industry standards and regulations.
 - iii. **Fairness and Transparency:** Avoid biases in AI decision-making and maintain transparency with construction stakeholders.
- 4.3.8. Monitor Return on Investment and Long-Term Impact**
- I. **Measure Outcomes:** Regularly evaluate the impact of AI on project timelines, costs, safety, and quality.
 - II. **Feedback Loop:** Collect feedback from users, such as Architects, Engineers, and Project Managers, to enhance AI tool functionality and usability.
 - III. **Strategic Alignment:** Ensure AI adoption aligns with the organisation's long-term goals and vision.

By adopting this implementation strategy, construction and project management firms can harness AI to optimise processes, reduce costs and risks, strengthen safety, improve decision-making, and enhance productivity across the project lifecycle.

5. Conclusion and Further Research

The construction and project management industry has experienced a significant digital transformation,

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primarily driven by Artificial Intelligence (AI) integration. Through a systematic literature review, this study explored the applications of AI within the industry and highlighted its associated benefits.

However, despite its transformative potential, the adoption of AI in construction is not without challenges, which the study also examined. To address these, the study proposed an AI implementation strategy tailored to the construction industry, aiming to optimise processes, reduce costs and risks, enhance decision-making, and boost productivity throughout the project lifecycle. Additionally, the study emphasised the need for further research to establish standardised AI regulatory and ethical frameworks for the construction sector. This includes the development of standardised data collection processes that prioritise data privacy and cybersecurity strategies.

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