# Application of AI in the Construction Industry: A Systematic Review

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## ABSTRACT

The construction industry continues to face persistent challenges such as cost and time overruns, safety risks, low productivity, and labor shortages. Despite its economic significance, the sector remains one of the least digitized globally, limiting its ability to address these challenges effectively. Artificial Intelligence (AI), as an advanced digital technology, has demonstrated the potential to transform traditional construction practices, similar to its impact on manufacturing, retail, and telecommunications.

This study presents a systematic literature review of AI applications in the construction industry, aiming to identify dominant application areas, commonly adopted AI techniques, and existing research gaps. The review was conducted in accordance with the PRISMA 2020 guidelines to ensure transparency and methodological rigor. Relevant peer-reviewed studies published between 2015 and 2025 were identified through structured searches of Scopus, Web of Science, Science Direct, and Google Scholar. Over 200 records were initially retrieved. After duplicate removal and multi-stage screening, 15 studies met the inclusion criteria and were selected for in-depth qualitative analysis.

The findings indicate that AI has been applied across key construction domains, including structural health monitoring, safety and risk management, design and pre-construction planning, sustainability, waste management, and on-site robotics. Machine learning and neural network-based approaches were the most frequently used techniques. While the reviewed studies demonstrate AI’s strong potential to improve efficiency, safety, and sustainability in construction projects, significant challenges remain, particularly regarding data quality, lack of standardization, system integration, and user trust. This review provides a consolidated overview of AI applications in construction and outlines critical directions for future research and industry adoption.

**Keywords:** Artificial intelligence; Construction industry; Construction project management; Systematic review; PRISMA

## INTRODUCTION

Artificial Intelligence (AI) refers to computer systems designed to perform tasks that normally require human intelligence, including learning, reasoning, pattern recognition, and decision-making. By analysing large volumes of structured and unstructured data, AI systems can identify complex patterns and generate insights that support informed and timely decisions. Through continuous learning, these systems can improve performance and accuracy over time [1].

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Construction projects are inherently complex, involving significant financial investments, multiple stakeholders, and highly interdependent activities. These characteristics make effective management challenging when relying solely on traditional tools and human judgement. Consequently, construction projects worldwide frequently experience schedule delays, cost overruns, safety incidents, and low productivity levels. To address these persistent challenges, the construction industry has increasingly explored Industry 4.0 technologies, particularly AI, to enhance project planning, monitoring, and performance optimization [2].

Despite this growing interest, construction remains one of the least innovative and least digitalized industries globally. Compared with sectors such as manufacturing and telecommunications, construction productivity has grown at an estimated rate of only about 1% annually over the past two decades [3]. This slow growth is largely attributed to the industry's fragmented structure, project-based operations, and reliance on traditional practices.

Recent advancements in AI offer opportunities to overcome these limitations. AI can support predictive analytics, optimize scheduling and cost estimation, automate hazardous and repetitive tasks, and improve safety management. By analyzing data from design models, project schedules, site sensors, and images, AI systems can predict project outcomes and support proactive decision-making. Furthermore, AI-driven robotics and automation can reduce human exposure to high-risk activities, thereby improving site safety and consistency [4,5].

Although research on AI in construction has increased significantly, existing studies are often fragmented, focusing on specific technologies, applications, or regional contexts. This fragmentation makes it difficult to obtain a comprehensive understanding of how AI is applied across the construction project lifecycle. To address this gap, this study adopts the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to systematically identify, screen, and synthesize relevant literature on AI applications in the construction industry.

The objectives of this study are:

1. To systematically review existing literature on the application of Artificial Intelligence in the construction industry.
2. To identify dominant AI application areas and highlight key research gaps for future studies

## METHODOLOGY

This study employed a systematic literature review approach to examine AI applications in the construction industry. The review process followed the PRISMA 2020 guidelines to ensure transparency, consistency, and reproducibility.

### Search Strategy

A comprehensive literature search was conducted using four academic databases: Scopus, Web of Science, Science Direct, and Google Scholar. Scopus and Web of Science were selected as primary sources due to their extensive coverage of high-quality peer-reviewed journals, while Science Direct and Google Scholar were used to enhance coverage and validate relevant publications.

The search strategy combined AI-related keywords (artificial intelligence, AI, machine learning, deep learning, computer vision, robotics*)* with construction-related terms (construction industry, construction management, project planning, safety, cost estimation, scheduling, design optimization, building information modelling (BIM)*)*. Searches were limited to titles, abstracts, and keywords. The publication period was restricted to 2015–2025 to capture recent technological development.

### Inclusion criteria:

- Peer-reviewed journal articles and conference proceedings

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- Studies explicitly addressing AI applications in construction or closely related AEC domains
- Publications written in English
- Studies published between 2015 and 2025

**Exclusion criteria:**

- Editorials, opinion papers, and grey literature
- Duplicate records
- Studies not directly related to the construction industry
- Studies addressing general digital tools without a clear AI component
- Studies with insufficient methodological detail or unclear outcomes

**Study Selection and Data Extraction**

The initial search identified 212 records. After removing duplicates, 180 records remained for title and abstract screening. Following this screening, 132 records were excluded due to lack of relevance. Full-text assessment was conducted on 48 articles, of which 33 were excluded because they lacked a clear construction focus, did not explicitly apply AI techniques, or exhibited weak methodological quality. Ultimately, 15 studies met all inclusion criteria and were selected for qualitative synthesis.

For each selected study, data were extracted on publication year, country, AI techniques used, application areas, data sources, and key findings.

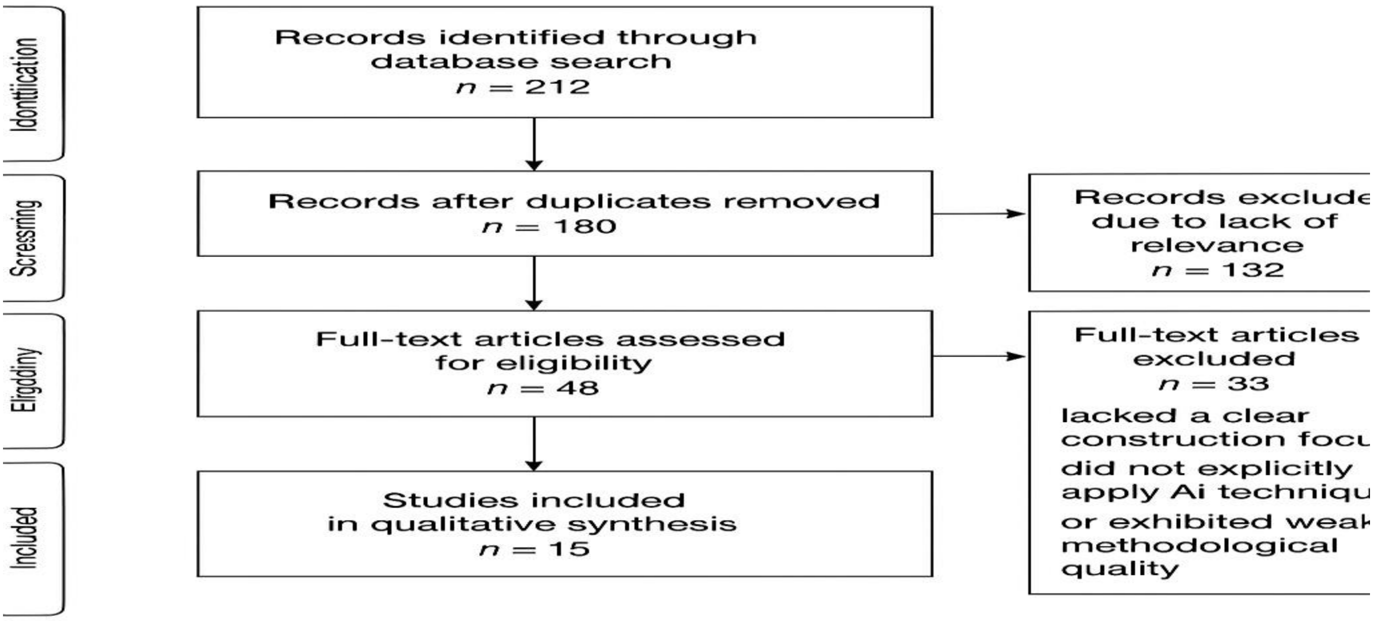


Figure 1. PRISMA 2020 flow diagram illustrating the study selection process.

## RESULT

The results of the systematic review are based on the qualitative analysis of 15 selected studies. These studies demonstrate the application of AI across multiple construction domains, including structural health monitoring, safety and risk management, design and pre-construction planning, sustainability, waste management, and on-site robotics.

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Machine learning and artificial neural networks were the most frequently adopted AI techniques, followed by deep learning, computer vision, reinforcement learning, and digital twin technologies. A significant proportion of studies focused on safety-related applications. For example, neural network-based models were used for structural damage detection, while computer vision systems enabled real-time monitoring of personal protective equipment compliance and hazardous site conditions.

Design and pre-construction planning applications were also prominent. Several studies reported that AI-enabled BIM and sensor integration reduced design conflicts and improved coordination during early project stages. More recent studies emphasized emerging themes such as explainable AI, human-centred AI, and sustainability, highlighting the importance of transparency, user trust, and environmental performance.

Overall, the findings indicate increasing adoption of AI technologies across construction project phases, although most applications remain at pilot stages.

**Table 1. Summary of selected studies on AI applications in the construction industry**

| S/N | Author (Year) | AI Technologies | Construction Area | Key Findings / Application |
|---|---|---|---|---|
| | | | | |
| 1 | Hooda et al. (2021) | Artificial Neural Networks (ANN) | Structural Monitoring | The project involves the automated detection of structural damage in building systems. |
| 2 | Owolabi et al. (2022) | AI-enabled BIM, Sensor Fusion | Design and Pre-construction | Integration of sensors with BIM significantly reduced design conflicts. |
| 3 | Chen & Ying (2022) | Metaheuristic Programming Algorithms (MPA), ML, DL, ANN | Evolutionary Review | I have reviewed over 30 years of AI development in AEC, which shows a shift from rule-based systems to deep learning. |
| 4 | Regona et al. (2022) | Machine Learning, Deep Learning, Big Data | Industry Adoption | The study identified a lack of data standards as a major barrier to global AI adoption. |
| 5 | Imran et al. (2022) | Computer Vision, Natural Language Processing | Safety and Productivity | The system has enabled real-time PPE detection and automation of hazardous construction tasks. |
| 6 | Pan & Zhang (2023) | Deep Learning, IoT, Digital Twins | Smart Construction Management | Identified six integration clusters forming a digital backbone for BIM–AI systems. |
| 7 | Rafsanjani & Nabizadeh (2023) | Human-Centred AI, NLP, Machine Reading | Human–AI Interaction | The emphasis was on AI systems that support, rather than replace, human decision-making. |
| 8 | Ivanova et al. (2023) | Digital Twins, Genetic Algorithms | Crane Safety | Reduced collision risks through real-time site simulation. |

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|---|---|---|---|---|
| 9 | Adeloye et al. (2023) | Explainable AI, IoT | Trust and Adoption | Demonstrated that explainable AI improves user trust and acceptance. |
| 10 | Datta et al. (2024) | Convolutional and Recurrent Neural Networks | Project Forecasting | Used RNN models to predict project recovery after schedule delays. |
| 11 | Feng et al. (2024) | Reinforcement Learning | Sustainability | Optimised HVAC operations to significantly reduce carbon emissions. |
| 12 | Adewale et al. (2024) | IoT, Digital Twins, Reinforcement Learning | Waste Management | Reported up to 40% reduction in construction site waste. |
| 13 | Hriday & Rehman (2025) | Genetic Algorithms, NLP, Ensemble Models | Cost Performance | Quantified measurable cost savings linked to increased AI adoption. |
| 14 | Adebayo et al. (2025) | Predictive Analytics | Industry Trends | Analysed the transition of the AEC sector into the Fourth Industrial Revolution. |
| 15 | Ren & Kim (2025) | Sense–Think–Act Framework, ML, RL | On-site Robotics | Defined an operational framework for autonomous construction robots. |

# DISCUSSION

This section critically discusses the findings of the systematic review by synthesising evidence from the selected studies, comparing AI techniques across application areas, and highlighting methodological limitations and research gaps. In line with the reviewer's suggestions, the discussion moves beyond description to analytical comparison and evaluation.

**Distribution of AI Applications Across Construction Phases**

The reviewed studies demonstrate that Artificial Intelligence is being applied across multiple phases of the construction project lifecycle, including design and pre-construction planning, on-site operations, safety management, sustainability, and post-construction monitoring. However, the distribution of research is uneven. A large proportion of studies focus on on-site safety, risk management, and monitoring, while fewer studies address strategic planning, procurement, and long-term asset management.

This imbalance suggests that AI adoption in construction is currently driven by problems that are highly visible and data-rich, such as accident prevention and site monitoring. In contrast, areas that require integrated organisational data and long-term decision-making remain underexplored, indicating a clear opportunity for future research.

**Comparison of AI Techniques and Their Effectiveness**

Across the selected studies, machine learning (ML) and artificial neural networks (ANNs) were the most frequently applied AI techniques. These methods were particularly effective in pattern recognition tasks, such as structural health monitoring, safety compliance detection, and project performance forecasting. For example, ANN-based models demonstrated strong performance in detecting structural damage, while recurrent neural networks were effective in predicting schedule recovery patterns.

More advanced techniques, such as reinforcement learning (RL) and digital twins, were primarily applied in sustainability and smart construction management contexts. While these approaches showed promising results—

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such as energy optimisation and waste reduction—their implementation often relied on simulated or controlled environments. This raises concerns about their scalability and reliability under real-world construction conditions. Overall, simpler ML-based models appear more mature for industry deployment, whereas advanced AI systems remain largely experimental.

**Emerging Themes: Explainable and Human-Centered AI**

Recent studies have begun to shift attention from purely technical performance toward human-centered and explainable AI (XAI). The reviewed literature highlights that lack of transparency remains a major barrier to AI adoption in construction. Explainable AI approaches were found to significantly improve user trust, particularly among construction professionals who rely heavily on experience-based decision-making.

Human-centered AI frameworks argue that AI should augment rather than replace human expertise. This perspective is particularly important in safety-critical applications, where over-reliance on opaque AI systems could introduce new risks. However, despite growing interest, empirical evaluations of XAI and human-centered approaches remain limited, indicating a gap between conceptual frameworks and practical implementation.

**Sustainability and Environmental Performance Implications**

AI applications targeting sustainability demonstrated measurable benefits, including reduced energy consumption, lower carbon emissions, and significant reductions in construction waste. Reinforcement learning-based energy management systems and digital twin-enabled waste tracking systems showed particularly strong potential.

Nevertheless, most sustainability-focused studies were conducted as case studies or simulations, often using limited datasets. As a result, their findings may not be fully generalizable across different project types or geographic regions. Future research should focus on large-scale, longitudinal studies to validate the environmental benefits of AI in diverse construction contexts.

**Methodological Limitations in Existing Studies**

Despite promising outcomes, the reviewed literature exhibits several methodological limitations. Many studies rely on small, project-specific datasets, which restricts model generalization. Additionally, inconsistent data formats, lack of standardized benchmarks, and limited reporting of model validation procedures reduce reproducibility.

Another key limitation is that a significant number of studies remain at the pilot or prototype stage, with few demonstrating sustained implementation in real construction projects. This highlights a gap between academic research and industry adoption, reinforcing the need for stronger collaboration between researchers and practitioners.

**Implications for Industry Practice and Policy**

From a practical perspective, the findings suggest that AI can deliver tangible benefits in construction when supported by high-quality data, standardized workflows, and user training. Industry stakeholders should prioritize AI applications with proven reliability, such as safety monitoring and predictive analytics, while gradually integrating more advanced systems.

From a policy standpoint, there is a need for data governance frameworks, interoperability standards, and ethical guidelines to support responsible AI deployment. Policymakers can play a critical role in facilitating data sharing and encouraging adoption through regulatory support and incentives

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## CONCLUSION

his study systematically reviewed recent literature on the application of Artificial Intelligence in the construction industry using PRISMA 2020 guidelines. The analysis of 15 selected studies shows that AI is increasingly applied across multiple construction activities, including safety management, design and planning, sustainability, waste reduction, and on-site automation.

While AI demonstrates strong potential to improve construction performance, its large-scale adoption remains constrained by data-related, technical, and organizational challenges. Future research should focus on developing standardized datasets, explainable AI systems, and long-term empirical studies that assess real-world performance and implementation feasibility. Strengthening collaboration between researchers, industry practitioners, and policymakers will be essential to fully realize AI’s benefits in the construction sector.

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