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# INTEGRATING ARTIFICIAL INTELLIGENCE INTO CONSTRUCTION: CHALLENGES, BENEFITS, AND STRATEGIES

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**Abstract**

The construction industry, despite being one of the largest contributors to the global economy, is one of the least digitized industries. The application of Artificial Intelligence (AI) offers a transformative opportunity to change the industry to be more efficient, safe, and cost-effective. This study analyses the current situation of AI adoption in construction, assessing 354 AI use-cases, 180 benefits, and 173 challenges identified by systematically reviewing 85 research articles from 2019 to 2024 obtained from Google Scholar and Science Direct databases. The identified use-cases, benefits, and challenges are categorized in ten, eleven, and six themes respectively based on their definition to provide systematic insight into the findings and facilitate better understanding by the readers. The identified Key AI application categories are safety monitoring, design automation, operational efficiency, and sustainability improvements. The most significant benefit categories identified by the analysis are improving operational efficiency, safety and risk management, and quality management. Additionally, the study also identifies the most salient categories for the identified challenges towards the use of AI as data scarcity, high implementation costs, lack of regulatory frameworks, and workforce training gaps. To overcome these challenges, the study suggests an eight-step AI adoption framework as a step-by-step pragmatic guideline for construction organizations for the successful implementation of AI, guiding them through 1) readiness assessment, 2) use-case identification, 3) data strategy development, 4) AI tool selection, 5) pilot testing, 6) workforce training, 7) continuous monitoring, and 8) scaling AI solutions. Future research should focus on validating the framework through real-world case studies, exploring industry-specific AI solutions, and developing standardized AI regulatory policies. By adopting AI systematically, the construction industry can transform into a data-driven, efficient, and innovative future, improving its long-term competitiveness and technological advancements.

**Keywords:** Artificial Intelligence (AI), Construction Technology, Automation in Construction, AI Adoption, Construction Transformation



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## 1. Introduction

The construction industry generates about 13% of world GDP [1] but is one of the least digitalized industries [2]. This lag presents challenges but also opportunities for digital transformation [3], [4]. The construction process is information-intensive [5], but traditional methods tend to result in inefficiencies, delay, and safety risks. Artificial Intelligence (AI), one of the pillars of digital transformation, promises to greatly assist in better decision-making, optimizing operations, and improving safety [6]. AI tools such as machine learning (ML), predictive analytics, and robotics allow for sophisticated insights and automation that go beyond human capabilities [7]. AI is being applied to planning, scheduling, risk management, and design optimization [8], [9], [10], [11], with industry investment projected at $4.51 billion by 2026 [10] and studies show that AEC startups related to AI raised $50 billion between 2020 and 2022 [1].

Despite this growth, AI use in construction is also held back by numerous barriers. These barriers include insufficient human-centric AI for AEC [12], technical challenges such as poor data quality and lack of

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generalizability [13], as well as demands for industry-specific models and risk analysis [14]. Motivated by such gaps, this study aims to investigate AI as an underlay for construction's transformation. The objectives of this study are:

- Reviewing available literature regarding AI in construction.
- Identifying use-cases, benefits, and challenges.
- Recognizing gaps in research and implementation.
- Proposing an operational AI adoption plan suited to construction operations.

## 2. Methodology

This study applied systematic review methodology drawn from [15] and divided into sections to ensure relevance, and analytical accuracy. The review drawn peer-reviewed, English-language documents from 2019 to 2024. The following search query was applied to the Web of Science database:

TI=(("Artificial Intelligence" OR "AI") AND ("construction" OR "construction industry" OR "construction sector" OR "building sector" OR "building industry" OR "AEC"))

The original keyword search resulted in 305 articles. Titles and abstracts were screened in order to select for relevance to AI use cases, challenges, and future developments in construction. Following exclusion of irrelevant studies, 85 full-text articles were included for in-depth thematic analysis (Fig. 1). These were categorized into:

- 40 research papers addressing use cases of AI.
- 22 academic papers outlining the benefits of AI.
- 23 papers discussing the challenges of AI deployment in construction.

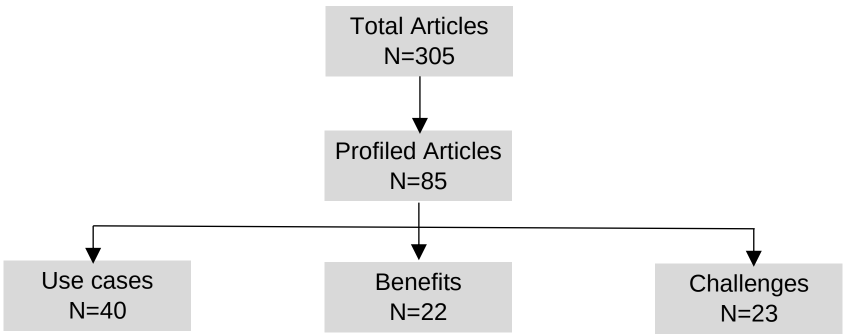


*Fig. 1. Systematic literature review process*

Each selected article was reviewed for quality in terms of objectives' clarity, soundness in methodology, and applicability to the research questions in the study. Limitations lie in possible exclusion of pertinent works on account of database scope and search terms, in addition to the dynamic development in AI technologies that can impact the study's future applicability.

## 3. Literature Review

### *3.1. AI Foundations and Core Elements*

#### *3.1.1. Definition of AI*

The term "Artificial Intelligence", as invented by [16], refers to a program that imitate human mental processes like reasoning, learning, perception, planning, and decision-making [9], [16]. Its definition has varied over disciplines but is generally viewed as designing computer-based systems that can accomplish tasks that demand human intelligence [17]. AI is traditionally divided into three classes:

- Artificial Narrow Intelligence (ANI) – task-specific AI, for example, image recognition [18].

- Artificial General Intelligence (AGI) – human-level flexible intelligence [19].
- Artificial Super Intelligence (ASI) – hypothetical future AI surpassing human intelligence [20].

Prominent definitions include [21], who define AI as an adaptive system to accomplish objectives based on external data, and [22], who defines AI as "intelligent behaviour involving understanding, logic, knowledge-sharing, and acting in complex situations." Other definitions include:

- [23] defines AI as “the oldest field within computer science, very broad, having to do with all aspects of mimicking cognitive functions for real-world problem solving and building systems that learn and think like people.”
- According to [24], AI is "the science of making machines do things that would require intelligence if done by humans."
- [25] states AI is “the discipline focused on developing methods for machines to perform tasks that are currently accomplished with greater human proficiency.”
- The U.S. government define AI as “The term 'artificial intelligence' means a machine-based system that can make predictions, recommendations or decisions concerning real or virtual environments based on specific human-defined objectives” [26].

This research embraces Nilsson’s definition because it is highly relevant to construction contexts in which reasoning and flexibility to adjust to situations are critical.

#### *3.1.2. Core Elements of AI in Construction*

This section focuses on the core elements of AI; problem definition, data, and models; highlighting their importance and application in the construction industry.

- **Problem Definition:** AI can solve multiple serious challenges facing construction, such as project delays, cost overruns, safety risks, and deficiencies in quality control. For instance, AI can forecast delays resulting from weather or equipment breakdowns and recommend mitigation alternatives [10]. Also, AI can enhance cost forecasting [7], improve safety by monitoring risks in real-time [27], and enhance quality control by providing systems that have been designed to detect faults [28].
- **Data:** In respect to any other field of application of AI, data remains fundamental for construction applications purposes. Construction projects generate immense amounts of internal (e.g., logs, sensor data) and external (e.g., weather forecasts, regulation data) data that, when effectively used, can provide actionable knowledge [29], [30]. Yet, there are still existing challenges including incomplete records, outdated information, and accurate data [28], [31]. Furthermore, data trustworthiness is ensured by verification mechanisms, while security is ensured by encryption and access control [32].
- **Models:** AI in construction commonly implements ML, Neural Networks, and Deep Learning (DL). ML entails algorithms being trained to recognize patterns [33], Neural networks are particularly effective for complex tasks such as image recognition and natural language processing [34], while DL applies multi-layer neural networks for improved accuracy [35]. Model creation involves data preparation, selecting features, and training using algorithms and techniques that best suit the specific construction problem being addressed [36], [37]. Also, common model evaluation metrics include recall, precision, and accuracy [38] and validation techniques, such as cross-validation and testing on new data, help ensure that the models generalize well to unseen data and do not overfit to the training dataset [39].

### *3.2. Use Cases, Benefits, and Challenges of AI in the Construction Industry*

#### *3.2.1. AI Use Cases in the Construction Industry*

Out of the 85 analysed academic articles, 40 directly discussed applications of AI within construction. 354 distinct use cases were extracted and categorized by their functional purpose by stage in the construction life cycle. The categorization aimed to identify patterns in the applications of AI technologies to actual construction processes and classify them in meaningful contexts. There were ten thematic categories of AI applications determined:

1. **Safety:** Comprises AI-based systems to monitor safety, anticipate possible danger, and detect risks in real time to prevent workplace injuries.
2. **Design:** Includes generative and optimized design techniques with AI to enhance accuracy, reduce cost, and accelerate project development.
3. **Operational Effectiveness:** Emphasizes automating manual processes and optimizing construction processes to eliminate manual labore and enhance productivity.
4. **Sustainability:** Includes applications to identify, reduce, and quantify waste to enable sustainable construction.
5. **Control:** Encompasses real-time observation and cost minimization to keep projects at budgeted levels and within designed specifications.
6. **Planning:** Helps with site layout planning, decision-making, and labore productivity prediction.
7. **Quality Control:** Facilitates real-time monitoring and detection of defects to ensure better workmanship and compliance.
8. **Energy:** Optimizes energy usage by predicting the load, controlling lighting/climate, and energy efficiency modelling.
9. **Scheduling:** Facilitates optimizing construction timelines via data-driven predictions.
10. **Estimation:** Facilitates project cost prediction, material usage planning, and budget optimization.

The study found that some AI use case categories were cited more than others, reflecting the industry's current focus and its highest priority areas. The topmost named use cases were:

- **Safety Monitoring (12 occurrences):** This use case indicates the high level of interest within the industry in enhancing worker safety. AI technologies such as computer vision and sensor-based systems are used to detect unsafe behaviours, detect near-miss conditions, and issue alerts to managers in real time. In light of the elevated fatality rate within construction, adoption of AI to manage safety proactively is gaining pace.
- **Design Generation (8 occurrences):** AI is revolutionizing the design stage by producing architecture and structural design based upon the constraints defined by the user. Such systems provide quick iteration and inexpensive conceptual design, allowing engineers to test more alternatives within a shorter time. Such frequent use case reflects that AI is becoming an integral part of early-stage design and planning.
- **Automation (8 occurrences):** AI-driven automation technologies reduce manual effort, primarily in the case of recurrent and time-consuming jobs such as excavating, bricklaying, and material transport. Automation not only enhances productivity but also addresses skilled labore deficiencies.
- **Safety Prediction (7 occurrences):** Predictive AI algorithms examine past incident data and environmental conditions to anticipate safety hazards prior to occurrence. This proactive capability plays a fundamental role in reducing hazards and minimizing incidents.
- **Hazard Identification (7 occurrences):** AI is widely adopted to detect hazards in real time via drone footage, site sensors, and machine learning. Such measures can identify hazardous conditions or lack of personal protective equipment (PPE) and help correct them faster.

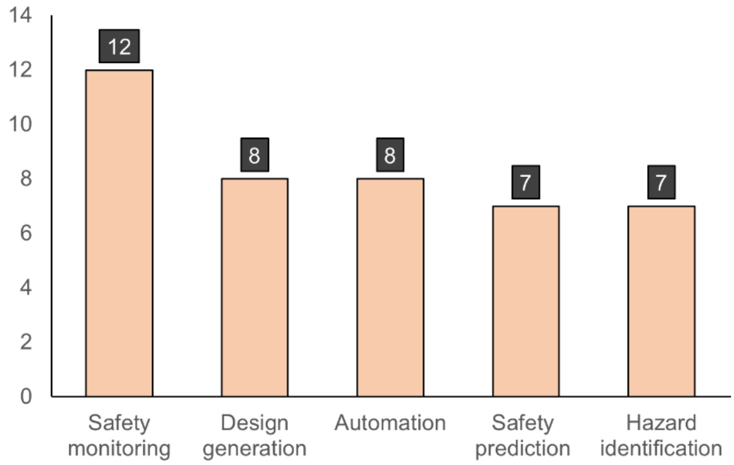


*Fig. 2. Topmost AI use cases in the construction industry*

*3.2.2. AI Benefits in the Construction Industry*

Out of the 85 papers reviewed, 22 directly referred to the benefits of AI in construction. 180 benefit instances were found and categorized under 11 categories. Categorization was done in accordance with recurring themes, by applying key terms and concepts related to AI-enhanced improvement within construction activities. The identified categories are as below:

1. **Operational Efficiency:** Includes benefits such as minimization of delays, improved workflow management, and automation of routine tasks.
2. **Safety and Risk Management:** Encompasses predicting hazards in real time, preventing accidents, and increased site security.
3. **Quality Improvement:** Early detection of defects, improved compliance, and less rework are major benefits within this category.
4. **Cost savings:** Using AI helps the construction industry to improve cost predictions and enables optimum use of resources.
5. **Training and Skill Development:** Facilitates workforce development through AI-driven simulations, customized learning modules, and adaptive skill-building platforms.
6. **Collaboration and Communication:** Enabling AI in the construction industry can improve coordination and interchange of information between the project stakeholders, which is one of the most important benefits mentioned in the literature review.
7. **Data Management and Analytics:** This category points out the possibilities presented by AI in gathering, interpretation, and analytics of data in such a way that construction organizations can use predictive analytics based on past occasions to arrive at particular decisions.
8. **Productivity Enhancement:** Focuses on optimized labore and machine usage through AI-driven planning.
9. **Automation and Robotics:** Includes a wide variety of equipment, including automated systems, robots, and construction machinery powered by AI to eliminate repetitive duties, leading to enhanced productivity.
10. **Project Planning and Scheduling:** This category is based on AI's incorporative capabilities to assist construction projects to have improved time prediction and responsiveness to real-time adjustments.

11. **Environmental Impact:** Numerous research and frameworks indicated AI's involvement in the development of waste-adverse construction processes such as emissions, less material waste, and sustainable decision-making.

The most cited benefit categories reveal the extent to which AI is transforming project delivery and decision-making (Fig. 3). The classification of the 180 benefits extracted indicates the spheres of AI implementation in the construction industry.

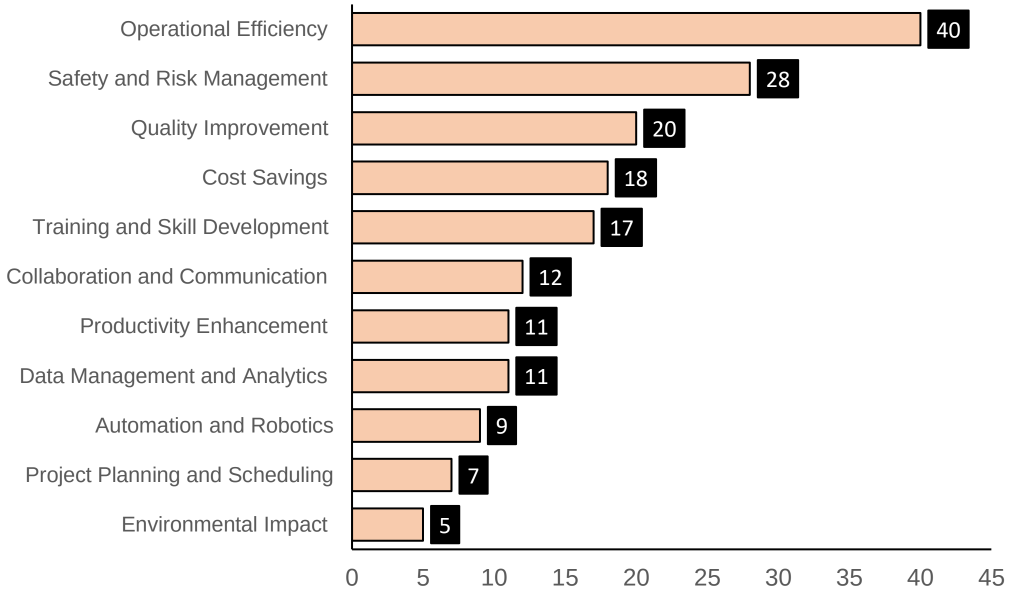


*Fig. 3. Topmost AI benefits in the construction industry*

- **Operational Efficiency (40 occurrences):** Most frequently cited, this is a testament to AI capability to rationalize processes in planning, resource allocation, and execution. AI applications cut down time lost, streamline logistics, and ensure project timelines are upheld by automating bottleneck processes. This category aligns with the industry's long-standing challenge of inefficiency and delay.
- **Safety and Risk Management (28 occurrences**): Many studies highlighted AI capability to enhance safety by monitoring, anticipating risks, and aiding in creating safer workplace environments, which enables construction organizations to move toward curbing workplace accidents and elevating the site's safety
- **Quality Improvement (20 occurrences):** AI's concern with quality assurance is also a common theme. AI technologies, such as computer vision and defect detection, offer scalable solutions to enhance quality by catching errors early and minimizing costly rework.
- **Cost Savings (18 occurrences):** Through improved forecasting, minimization of material wastage, and optimum usage of labore, AI is a huge cost-saving factor. Most studies associated AI's forecast analytics with decreased overruns, better bids, and lessened wastage of resources.
- **Training and Skill Development (17 occurrences):** As AI tools emerge, workforce development is also becoming a byproduct. Workers' adaptability to digital technologies and technical skills are established by many papers by mentioning AI-based simulators and training modules.
- **Collaboration and Communication (12 occurrences):** AI enhances collaboration and coordination between project teams by facilitating real-time information sharing and quicker, better-informed decision-making. Such capabilities are useful in complex construction projects with multiple stakeholders, where collaboration is critical to success.
- **Data Management and Analytics (11 occurrences):** AI streamlines large-scale construction data collection, organization, and analysis. With an increase in data-intense projects, AI extracts valuable insights, facilitating better-informed decision-making and eliminating or minimizing uncertainties.

- **Productivity Enhancement (11 occurrences):** AI directly impacts productivity in specific fields through automation of tasks, machine learning tools, and optimal use of resources.
- **Automation and Robotics (9 occurrences):** Although this area is not well defined within the literature, the possibility of using robotics and automation to substitute manual labore in dangerous or monotonous jobs is gaining traction.
- **Project Planning and Scheduling (7 occurrences):** The literature acknowledges AI's contribution to project scheduling and planning by using current information and forecasts of delays as necessary, but this aspect tends to be less popular.
- **Environmental Impact (5 occurrences):** The least frequent category in this research focuses on environmental benefits of using AI in construction. It aids the built environment in becoming more efficient, minimizing material waste, and making it more environmentally friendly.

*3.2.3. AI Challenges in the Construction Industry*

Among the 85 papers that were reviewed, 23 addressed challenges related to adopting AI in construction. There were 173 unique challenges listed and classified into six thematic categories, depending on their underlying causes and systemic effects on project delivery and adoption of technology. The identified categories are:

1. **Data:** The successful application of AI in construction is affected by several data-related challenges, including data accuracy, data integration, data quality, data scarcity, and data standardization.
2. **Compliance and Standards:** One of the main challenges is the absence of balanced regulations and standards promoting AI implementation within construction.
3. **Economic:** The high costs for implementing and maintaining AI, including capital input, infrastructure, and maintenance costs, deter its adoption among many construction organizations.
4. **Ethical:** Many construction organizations face organizational and cultural unwillingness to implement advanced technologies.
5. **Learning and Training:** Learning and training challenges include the lack of qualified professionals and the ongoing need for training programs to support AI adoption in construction.
6. **Technical:** Technical challenges also hinder the effective use of AI in construction including noise-related issues, lack of computational infrastructure, and integration issues with existing systems.

The breakdown of six categories of challenges illustrates the major pain points around AI adoption for the construction industry (Fig. 4) that must be addressed to fully realize AI's potentials.

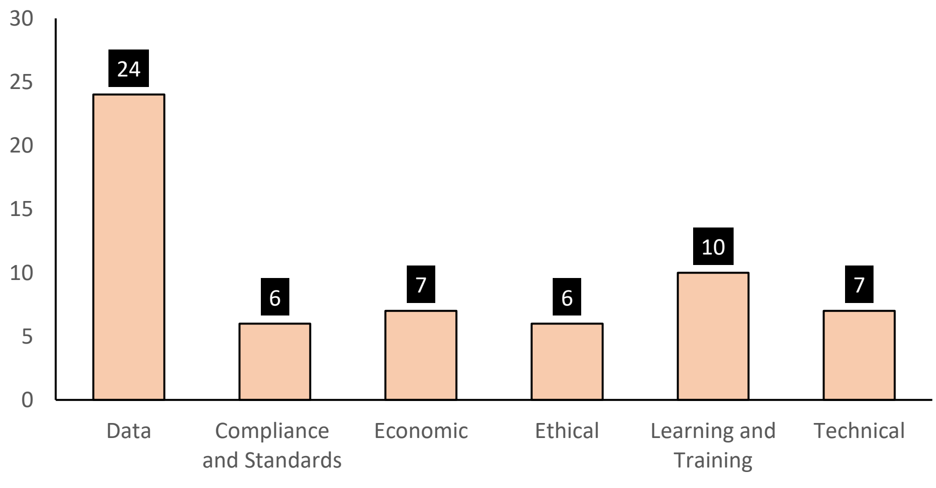


*Fig. 4. Topmost AI challenges in the construction industry*

- **Data (24 occurrences):** Issues surrounding data pose the biggest hindrances to AI adoption. The most frequent challenge in this category is data scarcity, where the construction industry lacks adequately large, high-quality datasets for efficient AI model training. One primary challenge is data accuracy, as inaccurate data can undermine the integrity and effectiveness of AI models. Additionally, integrating data from diverse sources is often cumbersome due to the heterogeneous nature of construction data, making seamless data consolidation difficult. Data quality is another major concern, as low-quality inputs result in unreliable AI predictions and insights. Furthermore, the absence of standardized data formats complicates integration efforts and impedes the smooth interaction between different systems.
- **Learning and Training (10 occurrences):** The construction industry faces a shortage of professionals who have knowledge of both AI as well as construction technology. Besides the shortage of skilled manpower, there is a persistent need for training initiatives to upskill current workers for efficient utilization of the AI applications. Thus, workforce development through strategic education as well as training is imperative for developing construction industry capacity as well as promoting the long-term adoption of AI technologies.
- **Economic (7 occurrences):** The associated high cost with AI technology, ranging from capital expenditure, infrastructure, qualified personnel, to ongoing maintenance, is a major barrier for construction organizations of all sizes, especially for smaller and mid-sized businesses. The cost-prohibitive requirements of installing AI underscore the necessity for affordable, scalable alternatives to enable a more widespread application of AI throughout the industry.
- **Technical (7 occurrences):** Technical hurdles of noise-related data issues, lack of dedicated computing infrastructure, as well as integration challenges for AI with legacy systems add to the adoption challenges. All these challenges highlight the need for investment in strong infrastructure and upgrading legacy systems to enable a conducive environment for AI.
- **Compliance and Standards (6 occurrences):** One of the main issues is the shortage of effective regulatory frameworks as well as standardized guidelines for using AI. Lack of standards for balanced regulations as well as compliance levels can make construction organizations uncertain about AI technology adoption. Without systemic regulation, there is a sense of reluctance as well as constrained business-wide progress, indicating a need for a systematic standards pathway for the effective application of AI.
- **Ethical (6 occurrences):** Ethical issues are a source of resistance to AI adoption in professionals. Ethical issues such as data privacy, job loss, and concern regarding transparency are consolidated by many people, resulting in a hesitant or cautious approach towards accepting new technologies. Clear communication, ethical frameworks, and inclusive approaches to innovation will be pivotal for mass adoption of AI.

## 4. Framework Development and Discussion

The construction industry is increasing the use of AI to resolve challenges such as cost overruns, delays, and safety risks. However, as with any other emerging technology, AI in construction must be systematically integrated into the organization so that the implemented solutions are appropriate and bring measurable benefits. Addressing the gap between AI's potential in theory and its usage on construction sites, this section develops a framework as a systematic and practical guide for construction organizations to implement AI. This framework as shown in Fig. 5. presents an eight-step process including Assess Readiness, Identify Use Cases, Build a Data Strategy, Select AI Tools, Develop a Pilot Project, Train the Workforce, Monitor and Iterate, and Scale and Sustain.

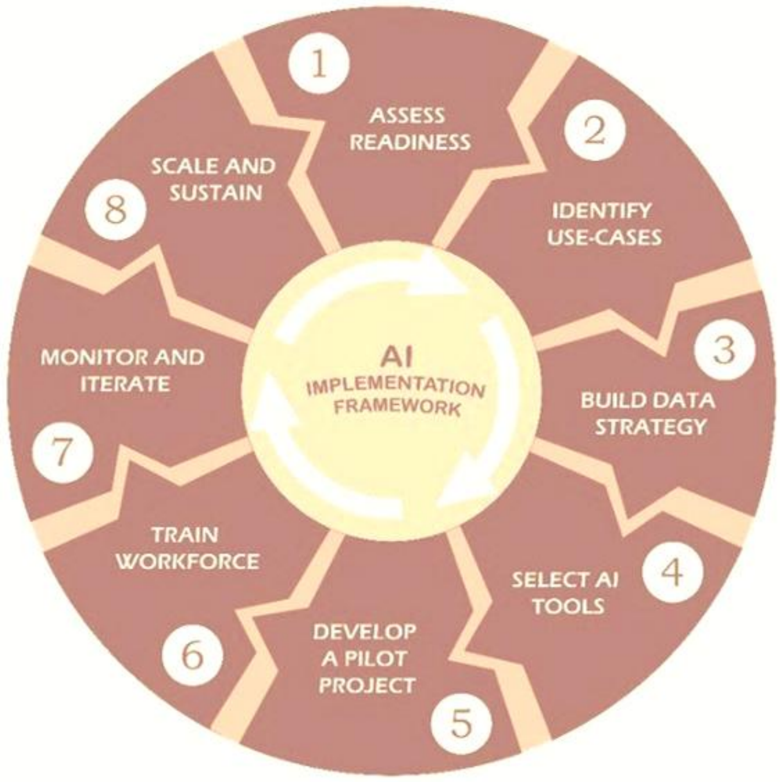


*Fig. 5. The proposed AI implementation framework*

### *4.1. Step 1- Assess Readiness*

The initial step in this framework is assessing the readiness of the organization to implement certain AI technologies. In this case, readiness assessment is aimed at ascertaining what current technological capabilities, information, and culture exist within an organization. Focus points are as below:

- To understand current inefficiencies that AI can address
- To measure digital maturity and data availability
- To evaluate internal support for change and innovation

Also, the following questions should be addressed:

- What is the specific problem or inefficiency in their construction process (e.g., cost overruns, schedule delays, or safety problems)?
- Which areas are perceived to be the most beneficial that would improve with AI technology?
- What levels of digitalization has the organization attained? Are any of the BIM/ AI tools utilized?
- Are there historical records from previous projects that can be accessed, and how relevant are they to AI?
- What financial and human resources are devoted for innovation or technology advancement in other domains?
- To what extent are key stakeholders, such as senior management and field teams, willing to embrace new AI technologies?

### *4.2. Step 2- Identify Use cases*

Having established readiness, the next step is to find high-impact, feasible use cases where AI has measurable benefits and aligns with organizational goals which involves mapping the challenges with possible AI technologies. The use cases are then prioritized in consideration of two criteria:

- **Impact:** The potential value that the AI solution could deliver.
- **Feasibility:** The degree of difficulty in achieving the implementation considering the data and the resources available in the organization.

In order to identify relevant AI use cases, the following questions are suggested:

- What final results are expected with the introduction of AI (for example, improving safety, controlling costs, or optimizing the schedule)?
- Are there simple or repeating activities in the current workflows that may be performed using AI automation?
- Which organizational challenges can AI technologies such as predictive analytics, anomaly detection, etc. address?
- Are there tools or procedures currently in place that provide redress to those challenges that may be improved with AI?
- What Key Performance Indicators (KPIs) will be used to measure the success of the selected use cases?

### *4.3. Step 3- Build Data Strategy*

AI projects are built upon data. This step focuses on developing a comprehensive data strategy to support AI implementation and the necessary steps should include:

- Inventory available data sources such as project schedules, material-supply logs, and safety reports.
- Evaluating data quality in terms of accuracy, completeness, and consistency.
- Addressing the identified gaps in available data by recruiting and outlining the additional data elements needed and the collection method.

Developing a data strategy encompasses the answering of the following questions:

- What types of data are currently collected, and how useful are they to the identified AI use cases (e.g., project schedules, site pictures/videos, etc.)?
- What is the quality of the data in terms of accuracy, reliability, consistency, and completeness, and what are the missing or deficient data?
- Where are the data in use stored, and how can they be retrieved?
- What rules and principles guide the storage of identifying, governing, securing, and maintaining the data?
- Are there any concerns about data privacy, security, and regulation compliance issues raised?
- What additional data will be required to implement the proposed AI solutions effectively?

### *4.4. Step 4- Select AI Tools*

The selection of proper tools is critical for the success of the AI initiatives. This step includes identifying AI technologies that apply to optimized use cases based on their compatibility with existing systems and scalability for future needs. While choosing the AI tools, some of the challenges that must be clarified are:

- Which tools are used for project management, safety supervision, or resource tracking, and can AI tools be used with such tools?
- Are there AI tools that cover the intended use cases?
- How much integration with existing systems and scalability should determine the choice of the tools?
- What expertise is required to deploy and maintain the selected AI tools?

### *4.5. Step 5- Develop a Pilot Project*

The step includes implementing a pilot project to test the usefulness of the selected tools and models before the AI integration is scaled up to cover the entire organization. Utilizing a controlled environment minimizes risks providing insights into the full-scale implementation's potential benefits and challenges. Designing a pilot project requires planning and may include responses to these questions below:

- How wide or narrow will the pilot project be?
- What are the precise metrics that will show whether the pilot was successful?
- Who will be the members of the pilot project team, and what responsibilities will they assume for this team?
- What methods will be used to evaluate the implemented methods and performance measurements during the pilot?

### *4.6. Step 6- Train the Workforce*

Effective adoption of AI involves commitment and engagement by employees at every level in the organization. Employees need to be educated in courses that familiarize them with utilizing AI-powered tools. The courses are tailored to diverse roles, ensuring managers, project directors, as well as work teams understand how AI enhances their work processes. Preparation of employees to adopt AI involves the following considerations:

- What level of familiarity does employees currently have with AI and its potential applications in construction?
- What training programs are to be designed to address knowledge gaps and ensure the effective use of AI tools?
- What training methods will be used to address various people, such as project managers, field teams, and top managers?
- Who is going to implement this training, and who will supervise it?

### *4.7. Step 7- Monitor and Iterate*

Continuous improvement is an integral part of this framework. After implementing suggested AI solutions, performance should be monitored using KPIs such as time savings, cost reductions, or safety improvements. Metrics help understand the evolution of target users and gather feedback on how AI-based solutions are being used. This helps ensure that AI-based solutions continue to evolve to suit the evolving needs of an organization and provide long-term and sustained value. The evaluators during the monitoring and iterative improvement phase prompt the following questions:

- How will KPIs be utilized to measure the performance of the created AI applications?
- How is feedback from users and stakeholders gathered and analysed?
- What are the procedures that will handle issues or inefficiencies that may develop during early deployment?
- How often will workflows and models used by AI be reviewed and updated to keep them running effectively?

### *4.8. Step 8- Scale and sustain*

The final step is to expand the successful solutions to other projects, departments, or business processes within the organization. The documentation of best practices and learning experiences in the pilot phase ensures an easy rollout. The organization also establishes a long-term AI roadmap that aligns its strategic objectives and positions to embrace future technologies. In order to scale and sustain the implementation of AI, the following questions should be answered:

- What were the most successful aspects of the pilot project which can now be implemented on a broader scale throughout the organization?
- Which additional departments, projects, or processes could benefit from similar AI solutions?
- What will it take in terms of financial, technological, as well as human resources, to scale these solutions?
- How will the best practices and experience from the pilot phase be recorded and shared?

## 5. Conclusion

The construction industry is constantly incorporating new technologies into the construction practice; such is the case with AI which helps overcome issues and creates new initiatives. This research carried out a systematic review of 85 peer-viewed publications from 2019 to 2024 and found 354 distinct AI use cases in the construction industry. The applications range across various areas such as safety monitoring, design optimization, scheduling, progress tracking, and sustainability. Besides these applications, the research also found 180 different benefits categorized in 11 including operational efficiency, safety and risk management, quality improvement, and cost savings as the top ones. Despite these promising developments, the research also revealed 173 challenges hindering the widespread adoption of AI in construction. Most frequently cited challenges include data-related issues such as data scarcity, data quality, and lack of standardization, economic challenges such as high costs of implementation, and inadequate skilled professionals. Ethical issues, organizational resistance, functional constraints, and lack of clear regulation mechanisms also identified that pose major barriers. This paper suggests an in-depth eight-step framework to assist construction organizations in overcoming such challenges. The framework steps include readiness assessment, use case identification, data strategy development, tool selection, pilot project implementation, workforce training, monitoring and iterating, and scaling. Following this framework, construction organizations can better align AI development to business strategies, achieve easier implementation, and realize long-term benefits in the different areas such as improved efficiency, safety, and competitiveness. Although the framework provides a useful starting point for digital transformation, more research will be necessary to test and enhance it in real construction environments. Future research will need to deploy the framework in a range of construction environments through in-depth case studies, adapt it to varied industries like residential, infrastructure, and industrial construction, and investigate its compatibility with complementary technologies such as Digital Twins, Internet of Things (IoT), and cloud-based control platforms. Furthermore, the development of common standards for the implementation of AI and data stewardship across industries will also be key to the development of trust, uniformity, and mass adoption. Collectively, these will expedite the transformation of the construction industry into a data-driven, intelligent, and resilient industry.

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