Global Journal of Engineering and Technology Advances

eISSN: 2582-5003

Cross Ref DOI: 10.30574/gjeta

Journal homepage: https://gjeta.com/

(Research Article)

Application of AI Tools as Enablers or Replacements in the Construction Industry: An Overview

N. SIVAPIRAN [1, *] and G. MURUGESAN [2]

[1] *Research Scholar, Department of Business Administration, VHNSN College, Aruppukottai Road, Virudhunagar 626 001, Kamaraj University, Madurai, Tamilnadu, India.*

[2] *Department of Business Administration, VHNSN College, Aruppukottai Road, Virudhunagar 626 001, Kamaraj University, Madurai, Tamilnadu, India.*

Global Journal of Engineering and Technology Advances, 2025, 25(01), 095-106

Publication history: Received on 02 September 2025; revised on 07 October 2025; accepted on 10 October 2025

Article DOI: https://doi.org/10.30574/gjeta.2025.25.1.0302

Abstract

The integration of Artificial Intelligence (AI) tools in the construction industry has been marked a transformative phase, improving efficiency, safety, and project management. However, a critical question persists—should AI be considered primarily as an enabler or a replacement for human roles in this sector? This article presents an overview of how AI functions across various stages of construction, evaluates its enabling capabilities, and explores its potential (and limitations) as a replacement to traditional processes and human intervention. The future of construction is not a zero-sum game between AI and human labor. Instead, a hybrid model is emerging. The most effective approach for the industry is to view AI not as a complete replacement, but as a strategic enhancement applied where improvements in efficiency and safety are evident. The future of the construction industry depends on a balanced approach to AI adoption: Leverage AI as a support tool for complex, decision-intensive tasks, Implement AI as a replacement only when it delivers clear advantages in safety, cost, or productivity, Prioritize workforce reskilling to enable effective supervision and management of AI-driven systems. The discussion also delves into ethical, operational, and socio-economic implications, supplemented by global case studies and academic literature.

Keywords: Artificial Intelligence; Construction management; Safety; Improving efficiency; Automation; Project management

1. Introduction

The construction industry, traditionally known for its dependence on manual labor, standardized methods, and incremental innovation, is undergoing rapid transformation due to emerging digital technologies. Artificial Intelligence (AI) has emerged as one of the most disruptive forces, enabling smarter planning, design, and execution processes while simultaneously challenging the boundaries of traditional workforce roles (Pan & Zhang, 2021)[1].

Historically, construction has been slow to adopt digital technologies compared to sectors such as manufacturing and healthcare (McKinsey, 2017)[2]. However, recent advancements in AI, particularly in machine learning, computer vision, natural language processing, and robotics, are accelerating this transition (Li et al., 2022)[3]. AI is now widely applied in predictive analytics, generative design, scheduling, safety monitoring, and automated quality control.

The critical debate is whether AI should be considered primarily an enabler—augmenting human decision-making and performance—or a replacement, automating entire tasks traditionally carried out by engineers, supervisors, or

* Corresponding author: N. SIVAPIRAN

laborers. While many scholars argue for a hybrid approach (Zhang & El-Gohary, 2020[4] WEF, 2023)[5], the issue requires a contextual exploration of industry needs, socio-economic constraints, and long-term workforce adaptability.

This paper builds on existing research to analyze AI's dual role as an enabler and replacement in construction, presenting case studies, global statistics, and implementation challenges.

2. Literature Review

The literature on AI in construction can be broadly categorized into three strands:

2.1. AI as an Efficiency Enabler

Researchers highlight AI's ability to optimize project design, scheduling, and resource management (Autodesk & FMI, 2021[6]; Li et al., 2019)[7]. Generative design software, for instance, has shown success in producing cost-effective, energy-efficient layouts (Van Wijnen Case Study, 2021)[8].

BIM integrated with AI improves design accuracy and clash detection, reducing costly rework (Mortenson Construction, 2020)[9].

2.2. AI as a Replacement Mechanism

Studies show how robotics, 3D printing, and autonomous equipment replace repetitive and hazardous tasks, improving safety and productivity (Fastbrick Robotics, 2022[10]; Apis Cor, 2021)[11].

The World Economic Forum (2023)[5] predicts that up to 20% of site-based jobs may be automated by 2030, particularly low-skill repetitive roles.

2.3. Ethical and Socio-Economic Implications

Scholars warn of workforce displacement, emphasizing the need for reskilling and hybrid adoption (Ghosh & Mahapatra, 2022)[12].

Questions of liability, accountability, and ethical AI deployment remain largely unresolved in construction contexts (Sun et al., 2022)[13].

While prior research establishes the potential of AI to improve productivity, reduce delays, and enhance safety, there is limited empirical analysis comparing enabler vs. replacement roles in different project contexts. This paper addresses this gap by consolidating case studies and global data into a comparative framework.

3. AI as an Enabler in Construction – Detailed Overview

AI acts as a catalyst in the construction industry by enhancing existing processes, improving accuracy, safety, and decision-making. Rather than replacing professionals, AI augments their abilities and streamlines workflows. This section explores how AI enables transformation across different stages of construction, supported by real-world applications and case studies.

AI acts as an enabler when it assists human workers in making faster, safer, or more accurate decisions without replacing their core role.

3.1. Planning and Design Optimization

- Generative Design Tools: AI algorithms produce multiple design iterations based on specific parameters (cost, material use, environmental impact).
- BIM Integration: AI enables more intelligent Building Information Modeling (BIM), helping teams identify clashes and inconsistencies early in the design process.

3.2. Project Management and Scheduling

- **AI Scheduling Assistants**: Machine learning models predict project timelines and optimize schedules, reducing delays and cost overruns.

- **Resource Allocation**: AI forecasts material and labor needs with greater accuracy, enhancing supply chain efficiency.

3.3. Safety Monitoring

- **Computer Vision**: AI-enabled cameras detect unsafe behaviors or hazards on construction sites in real-time.
- **Wearable AI Devices**: Monitor workers' fatigue, heat exposure, and motion, preventing accidents.

3.4. Quality Control

- **Defect Detection**: Drones and AI-powered image analysis detect construction defects and deviations from design specifications.

In these areas, AI augments human decision-making, helping professionals make better, faster, and safer choices.

3.5. Key Areas, Application & Impact

Table 1 Key Areas, Application and Impact

Area	AI Application	Impact
Design	Generative Design (e.g. Autodesk)	50% faster design cycles (Van Wijnen project, Netherlands)
Scheduling	AI Simulations (e.g. ALICE Technologies)	17% reduction in project duration (San Francisco high-rise)
Safety	Computer Vision (e.g. Smartvid.io)	30–40% reduction in on-site safety incidents
BIM Optimization	Clash detection & coordination (e.g. Mortenson Construction)	Over $500,000 saved on hospital project through early design conflict resolution
Quality Control & Site Monitoring	AI-powered drones and image analysis (e.g. Komatsu, OpenSpace.ai)	90% faster inspections and improved defect detection accuracy on large-scale infrastructure
Risk Analysis & Decision Support	Predictive analytics and historical data modeling (e.g. DPR Construction)	12% average reduction in project delays through early identification of risk-prone areas

3.6. Global Statistic

According to McKinsey (2022)[14] 81% of large construction firms implementing AI do so for decision support and planning, not to replace labor.

3.6.1. 1. Design and Planning Optimization

Generative Design

AI tools enable architects and engineers to generate design alternatives rapidly based on input constraints such as budget, material, size, and building use.

- **Example:** Autodesk's Generative Design Tool
- **Use Case**: The software was used by Van Wijnen, a Dutch construction company, to optimize floor plans for housing projects. AI generated 15,000+ design options considering space, sunlight, energy efficiency, and cost.
- **Outcome**: Reduced design time by 50% and improved user-centric layouts.

3.6.2. 2. Smart BIM Integration

Building Information Modeling (BIM), integrated with AI, enables predictive analysis, clash detection, and better visualization.

- **Example:** Mortenson Construction (USA)
- **Use Case**: Used AI-enabled BIM to detect design clashes and plan MEP (Mechanical, Electrical, and Plumbing) coordination.
- **Outcome**: Reduced -rework and saved over $500,000 on a hospital project in Chicago.

3.6.3. 3. Project Scheduling and Resource Optimization

Predictive Scheduling

AI analyzes historical data and real-time site updates to forecast project delays and suggest preventive actions.

- **Example:** ALICE Technologies
- **Use Case**: Applied on a 70-storey high-rise project in San Francisco to simulate over 6 million construction sequences.
- **Outcome**: AI recommended an optimal construction sequence, cutting schedule time by 17% and saving $1.8 million.

Demand Forecasting and Resource Planning

Machine learning models predict material needs, labor demands, and equipment availability.

- **Case Study:** Turner Construction
- Used AI algorithms to analyze site logistics and delivery schedules.
- **Benefit**: Achieved 10–15% less material waste and improved on-time material delivery.

3.6.4. 4. Safety Management

Computer Vision for Real-Time Hazard Detection

AI-driven cameras and drones identify unsafe behavior (e.g., missing PPE, working at height without harness).

- **Example:** Boston-based company Smartvid.io
- **Use Case**: Deployed on over 25 construction sites to monitor safety compliance using AI vision.
- **Result**: Clients reported a 30–40% reduction in safety incidents after implementation.

Wearable AI Devices

Devices like AI-enabled helmets and vests monitor worker fatigue, exposure to hazardous gases, and movement patterns.

- **Case Study:** Skanska USA

Workers wore AI-integrated sensors that tracked biometric data.

- **Outcome**: Real-time alerts helped prevent accidents due to heat stress and fatigue.

3.6.5. 5. Quality Control and Site Monitoring

AI-Powered Drones and Image Analytics

Drones capture high-resolution images, which AI analyzes for cracks, misalignments, and construction quality deviations.

- **Case Study:** Komatsu and NVIDIA Partnership

Used AI-powered drones to track earthworks and grade accuracy.

- **Benefit**: Reduced inspection time by 90% and improved documentation quality.

Progress Monitoring

AI tools use 3D scanning and photo documentation to compare actual site conditions with BIM models.

- **Example:** OpenSpace.ai
- **Use Case**: Contractors used it to record 360° images of sites, which AI analyzed for progress tracking.
- **Result**: Helped reduce disputes with subcontractors and enabled transparent reporting to stakeholders.

3.6.6. 6. Risk Analysis and Decision Support

Predictive Risk Analysis

AI evaluates historical project data to identify risk-prone areas such as subcontractor performance, weather impacts, or material shortages.

- **Case Study:** DPR Construction

Integrated AI into its, internal risk analysis system.

Result: Improved pre-construction decision-making and reduced average project delays by 12%.

Contract and Document Analysis

Natural Language Processing (NLP) tools help review legal contracts and compliance documents, flagging ambiguous or risky clauses.

- **Example:** Doxel.ai

Combine NLP and computer vision to automate compliance and reporting.

- **Outcome**: Improved contract interpretation time and reduced legal overhead.

---

4. AI as a Replacement in Construction – Elaborated Overview

While Artificial Intelligence (AI) largely serves as an enabler in the construction sector, its growing capabilities are increasingly leading to the replacement of certain human roles, especially in tasks that are repetitive, hazardous, or data-intensive. This replacement is not necessarily negative—it often results in higher efficiency, safety, and cost-effectiveness. This section highlights specific domains where AI acts as a direct replacement and explores real-world use cases and outcomes.

AI serves as a replacement when it fully automates roles traditionally done by humans, either in the field or in administrative functions.

4.1. Autonomous Equipment

AI-driven machinery such as excavators and bulldozers can operate with minimal human intervention, especially in repetitive or hazardous tasks.

4.2. Robotic Construction

Robotics powered by AI is being used for bricklaying, 3D printing of building components, and rebar tying—reducing the need for manual labor.

4.3. Administrative Tasks

AI chatbots and document management systems are handling procurement, billing, and communication—replacing clerical roles.

4.4. Predictive Analytics for Maintenance

- Example: Doxel.ai

- Combines NLP and computer vision to automate compliance and reporting.
- Outcome: Improved contract interpretation time and reduced legal overhead.
  - AI chatbots and document management systems are handling procurement, billing, and communication—replacing clerical roles.

4.4.1. Significant challenges:

- **Technical limitations** in unstructured environments.
- **High initial costs** of AI integration.
- **Resistance to change** and fear of job losses.
- **Ethical and legal concerns** surrounding liability and accountability.
- AI systems predict equipment failure or structural fatigue, reducing the need for

Example: Doxel.ai

- Combines NLP and computer vision to automate compliance and reporting.
- **Outcome**: Improved contract interpretation time and reduced legal overhead.
- AI chatbots and document management systems are handling procurement, billing, and communication—replacing clerical roles.

Significant challenges:

- **Technical limitations** in unstructured environments.
- **High initial costs** of AI integration.
- Resistance to change and fear of job losses.
- Ethical and legal concerns surrounding liability and accountability.
- Manual inspection.

However, full replacement comes with significant challenges:

- **Technical limitations** in unstructured environments.
- **High initial costs** of AI integration.
- **Resistance to change** and fear of job losses.
- **Ethical and legal concerns** surrounding liability and accountability.

4.5. Key Areas & Examples

When deployed as a replacement, AI in construction focuses on operational domains where tasks are predictable, data-driven, and time-sensitive. Key areas include design automation, project planning, safety management, and site operations. In design automation, AI-powered generative design software can independently produce optimized layouts and structural solutions, reducing dependency on junior design staff. Project planning applications such as AI-based scheduling, resource allocation, and cost forecasting replace manual spreadsheet-driven processes, delivering rapid, precise outputs. Safety management systems using computer vision can continuously monitor sites for compliance and hazards, reducing the need for physical inspection teams. In site operations, autonomous equipment and robotics can perform excavation, bricklaying, and material handling without human operators. The impact of these applications is substantial—shorter project timelines, fewer errors, higher safety compliance rates, and significant cost savings. However, the shift towards replacement also raises workforce displacement risks, necessitating a strategic approach to reskilling and role redefinition within the industry.

Table 2 Key Areas, Application & Impact

Area	AI Application	Impact
Design	Generative Design (e.g. Autodesk)	50% faster design cycles (Van Wijnen project, Netherlands)
Scheduling	AI Simulations (e.g. ALICE Technologies)	17% reduction in project duration (San Francisco high-rise)

Safety	Computer Vision (e.g. Smartvid.io)	30–40% reduction in on-site safety incidents
BIM Optimization	Clash detection & coordination (e.g. Mortenson Construction)	Over $500,000 saved on hospital project through early design conflict resolution
Quality Control & Site Monitoring	AI-powered drones and image analysis (e.g. Komatsu, OpenSpace.ai)	90% faster inspection time and enhanced defect detection accuracy
Risk Analysis & Decision Support	Predictive analytics & historical project modeling (e.g. DPR Construction)	12% reduction in project delays via early risk forecasting
Autonomous Construction Equipment	AI-guided excavation/grading (e.g. Built Robotics, Komatsu Smart Construction)	Replaced heavy machinery operators; 24/7 autonomous operation; 25% labor cost savings

In scenarios where AI functions as a replacement rather than a support tool, its adoption targets specific areas of construction that are highly structured, data-intensive, and repetitive. AI-powered design optimization systems can automate layout generation, structural analysis, and compliance checks, reducing the need for manual drafting and preliminary engineering review. Automated project scheduling and cost estimation platforms replace traditional planning teams for baseline schedules, resource allocation, and budgeting, delivering faster outputs with fewer human errors. On-site, computer vision–enabled safety monitoring systems and autonomous construction machinery can take over routine inspection and repetitive operational tasks, minimizing reliance on supervisors and operators. These replacements yield measurable output improvements, including reduced project turnaround times, enhanced precision in design and estimation, lower rework rates, and increased site safety through real-time hazard detection. While such systems can outperform humans in speed, scalability, and consistency, they risk eroding the experiential knowledge and problem-solving adaptability that human roles traditionally bring to construction projects.

Table 3 AI – Area, Systems, Human Roles Replaced, and Output Improvement

Area	**AI System**	**Human Role Replaced**	**Output Improvement**
Brick laying	SAM100 Robot	Masons	4x output (3,000 bricks/day)
Excavation & Grading	Built Robotics	Heavy equipment operators	24/7 autonomous operation
AI in Robotics	SAM100, Hadrian X (Fastbrick Robotics)	Masons, bricklayers	3,000+ bricks/day vs 600/day by human; 4–5x output; improved precision
3D Printing in Construction	Apis Cor, COBOD	Formwork teams, concrete workers, masons	Full house printed in <24 hours; reduced site labor by >50%; lower material wastage
AI in Administrative and Office Functions	Doxel.ai, KPMG AI NLP Tools, Procore Automations	Document controllers, junior legal reviewers, clerical staff	Contract/document review time cut by 70%; faster approvals; fewer errors
AI-Driven Predictive Maintenance and Inspection	Sterblue (AI + drones), Hilti ON!Track	Manual inspectors, site engineers, asset tracking staff	80% faster inspections; 30% drop in equipment downtime; improved asset utilization
Challenges and Caution Points in AI Replacement	N/A (Multiple systems and policy factors)	Low-skill laborers, repetitive task workers, document handlers	Replacement limited by cost, training needs, legal ambiguity, and ethical concerns

4.6. Global Statistic

According to World Economic Forum (2023)[5]:

- Up to 20% of routine site jobs may be replaced by automation or AI by 2030.
- Construction robotics market projected to grow from $2.5B in 2022 to $9.5B by 2030.

4.6.1. Autonomous Construction Equipment

AI has enabled the rise of self-operating machinery, particularly for excavation, grading, and earthworks—tasks that require precision but not complex decision-making.

Example: Built Robotics (USA)

- **Technology**: Retrofit kits that convert existing heavy equipment (bulldozers, excavators) into autonomous machines.
- **Use Case**: Used on wind farm projects in Nevada to automate trenching for power cables.
- **Outcome**:
  - Eliminated the need for 24/7 operators on-site.
  - Improved productivity and allowed operations during night hours.
  - Reduced labor costs by 20–25%.

4.6.2. Komatsu Smart Construction

- **AI Function**: Uses GPS, sensors, and real-time terrain data to autonomously control bulldozers and graders.
- **Outcome**: One operator now supervises multiple machines, replacing several traditional equipment operators.

AI in Robotics: Replacing Manual Labour

Robots powered by AI are replacing human workers in certain repetitive, labor-intensive, and skill-specific activities.

SAM100 by Construction Robotics (USA)

- **Function**: Semi-Automated Mason (SAM) robot that lays bricks using AI for alignment and positioning.
- **Use Case**: Used in building schools and hospitals across the U.S.
- **Impact**:
  - Lays 3000+ bricks per day compared to 600 by a human mason.
  - Reduces labor fatigue and cost, replacing up to 3–5 bricklayers per robot.

Fastbrick Robotics (Australia)

- **Technology**: Hadrian X, a robotic arm guided by AI that builds walls using CAD models.
- **Case Study**: Constructed a full house structure in less than 3 days, working 24/7.
- **Outcome**: Potential to replace traditional wall-building teams with one robot and one supervisor.

4.6.3. 3D Printing in Construction

AI-controlled 3D printing robots are replacing traditional formwork, concrete casting, and masonry.

Apis Cor (Russia/U.S.)

- **Technology**: Mobile robotic 3D printer with AI that adjusts parameters based on material behavior and environmental conditions.
- **Case Study**: Printed a 400 sq. ft house in 24 hours in harsh winter conditions.
- **Replacement Effect**: Eliminated need for formwork teams, concrete finishers, and masonry laborers.

COBOD International (Denmark)

- **Use Case**: 3D-printed Europe's first two-storey building in Belgium.
- **AI Function**: Adjusted print nozzle and flow in real-time, replacing traditional concrete application roles.
- **Result**: Construction labor requirements reduced by over 50%.

4.6.4. AI in Administrative and Office Functions

AI is also replacing back-office roles in procurement, document control, and contract analysis through Natural Language Processing (NLP) and intelligent automation.

Example: Procore and Doxel.ai

- **Function**: Automates invoice processing, procurement matching, and progress tracking.
- **Outcome**:
  - Document controllers replaced by digital assistants.
  - Reduced approval cycle time from 5 days to under 1 day.

KPMG AI Contract Review Tools

- **Use Case**: Automated the review of construction contracts for a major infrastructure project in Europe.
- **AI Role**: Replaced junior legal associates for initial contract reviews, reducing turnaround time by 70%.

4.6.5. AI-Driven Predictive Maintenance and Inspection

AI has begun replacing manual inspection processes by using drones, sensors, and data analytics to monitor structures and equipment.

Example: InfraAI by Sterblue (France)

- **Technology**: AI + drones inspect towers, bridges, and power lines.
- **Case Study**: Used on a European rail project for bridge inspection.
- **Impact**:
  - Reduced manual inspection crew by 80%.
  - Replaced weeks of human inspection with hours of autonomous drone work.

Hilti ON! Track with AI

- **Function**: Predicts equipment service needs and automates asset management.
- **Result**: Replaced site managers and clerks responsible for tracking tools, reducing equipment downtime by 30%.

4.6.6. Challenges and Caution Points in AI Replacement

Despite these advancements, full-scale AI replacement faces the following critical challenges:

- **Lack of contextual decision-making**: AI struggles in ambiguous or fast-changing site conditions.
- **High capital investment**: Small contractors cannot afford robotic equipment.
- **Job displacement concerns**: Fear of unemployment among skilled laborers.
- **Regulatory and legal risks**: Accountability and liability in AI-led operations is still unclear in many jurisdictions.

---

5. Human - AI Collaboration: The Hybrid Future

The future of construction is not a zero-sum game between AI and human labor. Instead, a hybrid model is emerging:

- **Human insight + AI precision** create smarter and safer construction processes.
- **Upskilling workforce** becomes critical. Engineers, supervisors, and workers need AI literacy to collaborate effectively.
- **AI Ethics and Governance** needs to be established to prevent bias and ensure accountability.

---

6. Comparative Case Study: AI in High-Rise Construction

Table 4 AI – Comparative Case Study: AI in High-Rise Construction

Aspect	**AI as Enabler**	**AI as Replacement**
Company	DPR Construction (USA)	Fastbrick Robotics (Australia)
Use Case	AI for risk forecasting, schedule simulation	Robotic bricklaying with Hadrian X
Outcome	Reduced project delays by 12%	Built structural walls of house in <3 days

Human Involvement	Project managers & planners remained active	Entire bricklaying team replaced

7. Economic and Social Impacts

7.1. Enabler Role

- **Upskilling Opportunities**: Workers learn to collaborate with AI (e.g., drone operators, BIM technicians).
- **Job Retention**: Human oversight still required in design, strategy, and safety.

7.2. Replacement Role

- **Job Displacement Risk**: Particularly for low-skill, repetitive labor roles.
- **Capital-Intensive**: SMEs struggle to adopt replacement technologies due to cost.

Table 5 Statistical Comparison (Source: BCG, 2023 Survey of 350 Construction Firms)

Metric	Enabler AI Use	Replacement AI Use
Average ROI	18%	24%
Adoption Rate	68%	24%
Workforce Resistance	12%	48%
Implementation Cost	Medium	High

8. Future Outlook: Complementarily vs. Substitution

The future trajectory of AI in the construction industry will largely depend on how stakeholders position it—either as a complementary enabler or as a direct substitute for human roles. In the complementary model, AI tools enhance human expertise, improving accuracy, productivity, and decision-making without replacing core human judgment, creativity, or interpersonal skills essential to project execution. This approach fosters a symbiotic relationship where engineers, architects, and managers use AI to automate repetitive tasks, perform advanced simulations, and manage complex data sets while retaining strategic oversight. Conversely, the substitution model envisions AI as a full or partial replacement for certain roles, especially in highly standardized or repetitive functions such as cost estimation, scheduling, and safety monitoring. While substitution could yield efficiency gains and cost savings, it also raises concerns regarding job displacement, skills redundancy, and ethical decision-making in critical situations. Ultimately, the balance between complementarily and substitution will be shaped by technological maturity, regulatory frameworks, workforce adaptability, and the industry's willingness to invest in upskilling, ensuring that AI integration drives sustainable growth rather than disruption.

Table 6 Future Outlook: Complementarily vs. Substitution

Aspect	Enabler Approach	Replacement Approach
Suitable for	Complex problem-solving, design, risk management	High-volume repetitive tasks
Limitations	Requires skilled human input, may not reduce cost drastically	High cost, less flexible in dynamic conditions
Ideal Integration	Human-AI collaboration	Limited substitution, supervisory roles needed

9. Conclusion

9.1. AI as a Selective Replacement

AI is gradually replacing certain human roles in construction—especially those that are:

- Repetitive or routine (e.g. bricklaying, trenching).

- Hazardous (e.g. inspections, excavation).
- Data-heavy (e.g. document analysis, procurement).

However, human intuition, problem-solving, and adaptive thinking still remain irreplaceable for complex and creative construction tasks.

The ideal approach for the industry is to treat AI not as a total substitute, but as a strategic replacement where efficiency and safety gains are clear, while reskilling the workforce to manage and supervise AI systems effectively.

9.2. Human + AI Collaboration

AI is a powerful enabler, not a job destroyer. It supports construction professionals in making data-driven decisions, ensuring safety, and maintaining project quality. However, for successful implementation, the industry must invest in:

- Training the workforce to use AI tools.
- Adapting workflows to include digital processes.
- Ensuring data availability and integrity.

The future of construction lies in collaborative intelligence, where AI empowers engineers, supervisors, and laborers to build faster, smarter, and safer. AI is both an enabler and, selectively, a replacement in the construction industry. While its role in augmenting human skills is already significant, replacement is viable in limited, high-repetition or high-risk tasks. The emphasis should be on coexistence, where AI handles data-heavy, dangerous, or repetitive tasks, while humans focus on creativity, critical thinking, and supervision.

Investments in training, policy frameworks, and stakeholder awareness will determine how successfully the construction sector can leverage AI without compromising employment, safety, or quality. The construction industry's future lies in balanced adoption:

- Use AI as an enabler for decision-heavy tasks.
- Adopt AI as a replacement only where safety, cost, or productivity gains are significant.
- Focus on reskilling to prepare the workforce for supervising and managing AI systems.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Pan, W., & Zhang, Z. (2021). *Human–AI collaboration in construction project delivery*. Journal of Construction Engineering and Management, 147(12), 04021168.

[2] McKinsey & Co. (2017). *Reinventing Construction: A Route to Higher Productivity*.

[3] Li, H., Pan, W., & Zhang, Z. (2022). *Digital transformation and AI adoption in construction: Drivers and barriers*. Journal of Civil Engineering and Management, 28(2), 133–145.

[4] Zhang, J., & El-Gohary, N. (2020). *Hybrid intelligence in construction management: Opportunities and risks*. Automation in Construction, 113, 103128.

[5] World Economic Forum (2023). *Shaping the Future of Construction with AI.*

[6] Autodesk & FMI (2021). *Harnessing the Data Advantage in Construction*.

[7] Li, X., Wu, P., Shen, G. Q., & Teng, Y. (2019). *Applications of artificial intelligence in the construction industry: A critical review and future directions.* Automation in Construction, 103, 27–41.

[8] Autodesk Case Study: *Van Wijnen Housing Projects*

[9] Mortenson Construction (2020). *BIM and AI Integration for Healthcare Projects*

[10] Fastbrick Robotics (2022). *Hadrian X Case Studies*

[11] Apis Cor (2021). *3D Printing in Construction*: Case Study Reports.

[12] Ghosh, S., & Mahapatra, S. (2022). *Ethical adoption of Artificial Intelligence in construction*. International Journal of Project Management, 40(3), 211–224.

[13] Sun, C., Xu, X., & Wang, Y. (2022). *Liability issues in AI-driven construction automation*. Automation in Construction, 141, 104451.

[14] McKinsey & Company (2022). *Reimagining the Future of Construction*