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Artificial Intelligence in the Construction Industry: A Systematic Review of Emerging Opportunities and Prevailing Challenges

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Abstract*—This systematic review explores the application of Artificial Intelligence (AI) in the construction industry, focusing on its benefits, challenges, and future prospects. AI demonstrates significant potential to enhance productivity, drive innovation, and promote environmental sustainability by automating repetitive tasks, optimizing construction processes, and integrating seamlessly with Industry 4.0 technologies. These advancements facilitate real-time site monitoring, extend material lifespan, and enable the development of smart, adaptive buildings tailored to environmental demands—ultimately reducing operational costs and environmental impact. Despite these advantages, the implementation of AI in construction faces several challenges. The industry's fragmentation impedes data sharing and standardization, while high implementation costs, technological constraints, and ambiguous regulatory frameworks further hinder progress. Additionally, organizational resistance and limited digital skills among stakeholders highlight the need for cross-sector collaboration and capacity-building initiatives. The review also discusses emerging AI tools such as generative design and structural health monitoring, which have the potential to transform project management, design optimization, and safety assurance. By synthesizing findings from extensive literature, the study underscores AI's capacity to enhance sustainability and efficiency across construction activities. Nevertheless, to fully realize AI's transformative potential, systemic issues related to data governance and accessibility must be addressed. Establishing standardized data practices will be critical in advancing a technologically driven, smart construction sector.

***Keywords*—Artificial Intelligence, Industry 4.0, Construction Industry, Smart Buildings, Sustainability**

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I. Introduction

The construction industry, a cornerstone of worldwide economic growth, is experiencing a major change as it incorporates AI. It is due to the need for greater productivity, lower costs, and enhanced security at different stages of building construction [1]. AI technologies such as machine learning deep learning, and natural language processing provide fresh possibilities to drive a revolution in traditional building methodologies [2], [3], [4]. Yet, incorporating AI into the construction sector faces challenges that require systematic solutions to reach its potential. AI has many uses in construction, from architectural design, project management, and green building principles. For instance, AI can enhance the planning process of construction projects by increasing risk analysis and cost estimation through handling large datasets [5]. This capability is crucial as successful construction projects rely on accurate measurements and adequate resource management. AI technology like machine learning and deep learning is a key driver in the development of construction 4.0, smart operation, building management, and health monitoring [6]. This system automates repetitive tasks, thus improving productivity and lessening the risks of human error.

Despite its potential, the construction industry lags behind other sectors in the adoption of artificial intelligence (AI) technologies [7], [8], [9]. This is even more glaring when compared to the likes of healthcare, manufacturing and transportation industries [5], [10]. Also, as illustrated in Figure 1, the rate of AI integration within the construction sector remains comparatively slow [11]. This delay can be attributed to several factors, including the fragmented nature of the industry, which complicates data organization and management [5]. Integrating AI into traditional construction workflows also introduces technical challenges [12], particularly in developing robust AI models capable of functioning within the dynamic and complex environments typical of construction projects [13]. Additionally, the limited AI-related training and expertise among construction professionals further impedes widespread implementation [14]. This is as Douban [15] elaborated the importance of human experts for successful AI integration.

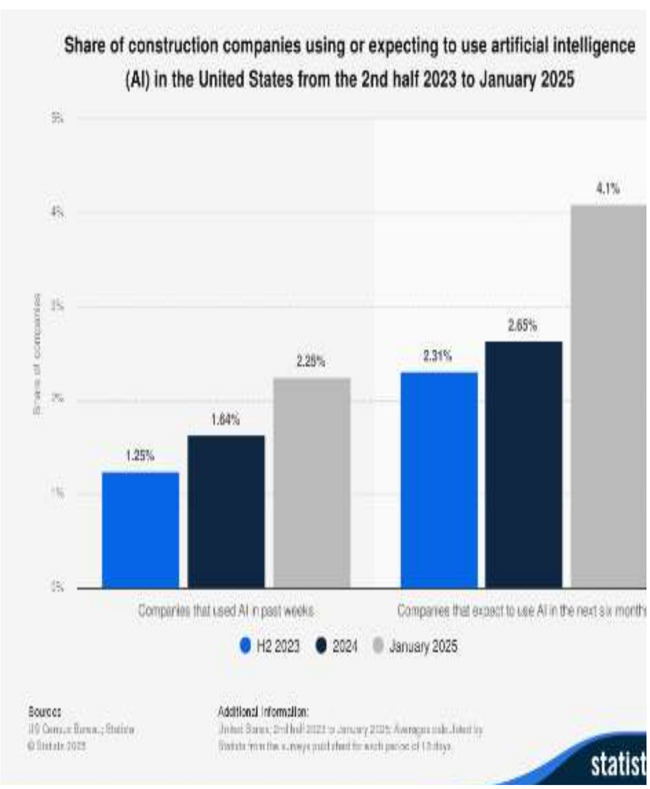

Fig. 1. Construction Companies' Adoption of AI in the US [6].

The incorporation of AI in construction is not only a matter of solving technical issues, but also resolving ethical and data privacy issues. With growing application of AI systems, it is crucial to ensure data security and ethical considerations in AI use [14]. Addressing these challenges necessitates the development of comprehensive frameworks and regulatory policies to govern the implementation and long-term integration of AI technologies in the construction sector.

Moreover, the potential of AI to advance sustainable construction practices cannot be ignored. AI significantly contributes to achieving sustainable development goals by promoting the efficient utilization of resources and minimizing waste throughout the construction process [14]. For example, AI-driven systems enhance circular economy strategies in construction by optimizing material selection, facilitating waste segregation, and improving recycling processes [16]. These applications yield both environmental benefits and economic advantages through material savings and enhanced resource efficiency.

The future is bright for AI in construction, and new technologies like generative AI and BIM will revolutionize the industry even more. Generative AI, through its capability to create content that seems man-made, opens up new possibilities in design and project management. AI and building information modeling (BIM) can, when combined, make decision-making processes more intelligent and well-informed [16], [17]. Nevertheless, to achieve these advantages, it is necessary to fill the existing knowledge gaps and facilitate cooperation among AI researchers and construction experts.

The construction industry is presented with significant opportunities alongside substantial challenges in the deployment of AI technologies. The effective integration of AI into construction practices is contingent upon addressing a range of technical, organizational, and ethical barriers. By successfully navigating these challenges and harnessing the transformative potential of AI, the industry can enhance operational efficiency, drive innovation, and promote sustainability. This study investigates the current state of AI adoption in construction, while also exploring prospective opportunities and challenges for future implementation.

II. Methodology

A. Research Design

The study design of this systematic review was structured to deliver a comprehensive synthesis of the existing body of literature on the application AI within the construction industry. Adopting the systematic review methodology, the research followed a rigorous and transparent protocol for the identification, appraisal, and synthesis of relevant studies, in accordance with the framework proposed by Snyder [18].

B. Inclusion and Exclusion Criteria

The scope of this review was defined by specific inclusion and exclusion criteria to ensure the selection of studies aligned with the research objectives. These criteria were applied systematically during the screening process to identify relevant and high-quality literature. The review focused on studies pertaining to the application of AI in the construction industry, limited to publications in English, including peer-reviewed journal articles, conference proceedings, and industry reports published between January 2015 and April 2025. This timeframe was chosen to capture the rapid evolution of AI technologies in recent years. Studies addressing AI applications outside the construction sector, lacking substantive analysis, or not available in full text were excluded from the analysis. A summary of the inclusion and exclusion criteria is provided in Table I.

TABLE I. SUMMARY OF THE INCLUSION AND EXCLUSION CRITERIA

Criteria	**Inclusion**	**Exclusion**
Focus	Studies on AI applications in construction (e.g., design, project management, BIM)	Studies on AI in unrelated fields (e.g., healthcare, finance)
Language	Published in English	Published in languages other than English
Publication Type	Peer-reviewed journals, conference proceedings, reputable industry reports	Non-peer-reviewed sources (e.g., blogs, opinion pieces, news articles)
Timeframe	Published between January 2015 and April 2025	Published before January 2015
Content	Empirical studies, case studies, or reviews with substantive analysis	Studies lacking data or analysis (e.g., abstracts only, promotional material)
Accessibility	Full-text available	Full-text unavailable

The inclusion and exclusion criteria presented in Table I helped to guide the search using a well-designed search string. The search string was carefully crafted to capture a wide range of relevant literature while maintaining specificity to the topic. The string combined keywords and Boolean operators to reflect the dual focus on AI and the construction industry. The final search string used was: ("artificial intelligence" OR "AI" OR "machine learning" OR "generative AI" OR "deep learning") AND ("construction industry" OR "building industry" OR "construction management" OR "BIM" OR "building information modeling") AND ("opportunities" OR "challenges" OR "applications" OR "benefits" OR "limitations"). This string was adapted slightly for different databases to account for syntax variations, ensuring consistency in the retrieval of relevant studies across platforms.

The literature search was conducted across multiple academic and industry-focused databases to ensure comprehensive coverage of the topic. The primary databases included Scopus, Web of Science, and IEEE Xplore, which are known for their extensive collections of peer-reviewed articles in engineering, technology, and AI-related fields. Additionally, Google Scholar was used to identify grey literature, such as industry reports and conference proceedings, that might not be indexed in traditional databases. The search was supplemented by a manual review of reference lists from key articles to identify any additional relevant studies.

C. Scoping Review

The scoping review process began with an initial search that yielded a broad overview of available materials on AI in the construction industry. Using the defined search string, the databases returned a total of 1,342 records. To refine this pool and arrive at the final set of studies, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework was employed as presented in Figure 2. First, duplicates were removed, reducing the number to 987 unique records. Titles and abstracts were then screened against the inclusion and exclusion criteria, excluding 789 studies that were irrelevant or did not meet the criteria (e.g., focused on unrelated industries or lacking substantive content). This left 198 studies for full-text review. During this stage, an additional 166 studies were excluded due to reasons such as unavailability of full text, insufficient focus on AI applications, or lack of empirical data. The final set comprised 32 studies, which were selected for their direct relevance to the opportunities and challenges of AI in construction, as well as their quality and depth of analysis. These studies included a mix of journal articles, conference papers, and industry reports, providing a balanced perspective on the topic.

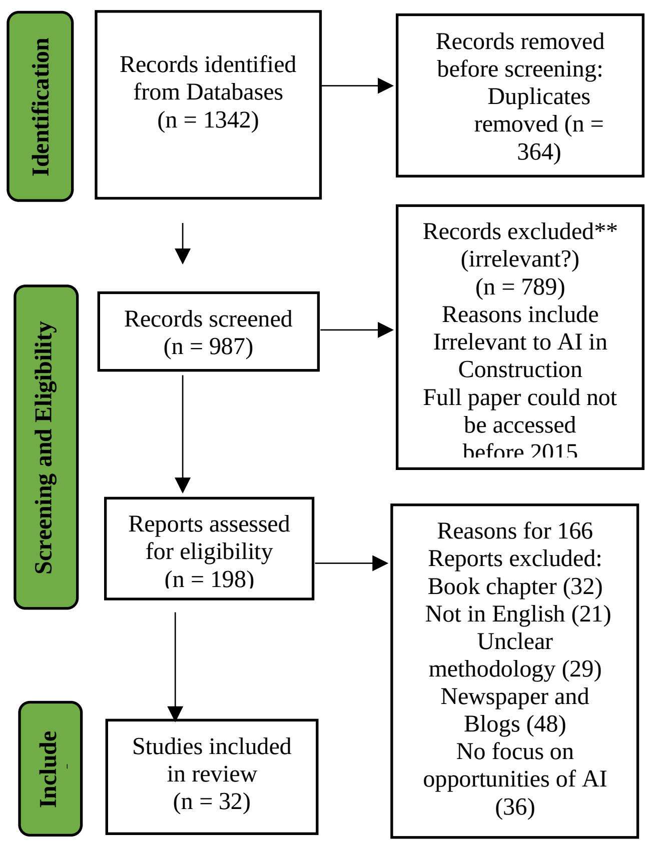

Fig. 2. PRISMA Flow Diagram

D. Data Analysis

Data from the 32 selected studies were analyzed using a thematic synthesis approach to identify patterns and insights related to the review's objectives as shown in Table 2. Each study was first read in full to extract key findings, which were then coded into categories such as "opportunities" (e.g., efficiency gains, design innovation), "challenges" (e.g., technical barriers, ethical concerns), and "emerging technologies" (e.g., generative AI, AI-BIM integration). A qualitative narrative synthesis was employed to summarize these findings, highlighting both common themes and divergent perspectives across the literature. Where applicable, quantitative data—such as reported cost savings or adoption rates—were tabulated to provide a clearer picture of AI's impact. The analysis also considered the context of each study (e.g., geographic region, project type) to assess the generalizability of findings. This iterative process ensured a comprehensive understanding of how AI is shaping the construction industry, culminating in evidence-based conclusions and recommendations.

TABLE II. CHARACTERISTICS OF STUDIES CONSIDERED

Author(s)	Aim and Objective	Findings	Contribution to Knowledge
[9]	Unravel AI applications, examine techniques, and identify opportunities and challenges in construction.	AI enhances profitability, efficiency, safety via ML, computer vision, robotics; challenges include data and adoption barriers.	Provides insights into AI's role in addressing construction-specific challenges and pathways to benefits.
[19]	Investigate AI technologies to improve construction productivity and identify adoption barriers.	AI improves productivity in slabs, steelwork, safety; barriers include technical, managerial, economic issues.	Identifies AI applications and barriers, aiding stakeholders in investment decisions for productivity gains.
[20]	Explore AI's potential in sustainable building lifecycles, its influence, and implementation challenges.	AI optimizes energy, maintenance, design; barriers include cost, data security, and implementation issues.	Highlights AI's role in sustainable building practices and key adoption challenges.
[21]	Review challenges of using data for AI (quality, privacy, etc.) and recommend solutions across industries.	Challenges include data quality, privacy, bias; solutions involve better data strategies.	Offers a broad framework for data strategies in AI, applicable to construction data management.
[22]	Investigate AI adoption rates, challenges, and potential in Germany's construction industry via survey.	AI enhances efficiency, safety; challenges include learning curve; growing interest signals a shift to data-driven models.	Provides professional perspectives on AI adoption, emphasizing practical applications and future potential.
[23]	Investigate industry-specific factors limiting robotics and automation adoption in construction.	Key challenges: economic (contractor/client), technical, work-culture, weak business case; no strong correlations found.	Clarifies barriers to automation, supporting stakeholders in devising mitigation strategies.
[17]	Explore opportunities and challenges of generative AI (GenAI) in construction, focusing on text-based models.	GenAI offers potential in content generation; challenges include adoption gaps; proposes a conceptual implementation framework.	Bridges knowledge gap on GenAI, offering a framework and future research directions for construction.
[24]	Review AI, ML, DL applications in construction for environmental and operational challenges.	AI predicts pollution, improves materials, safety; gaps remain in broader integration and real-world validation.	Demonstrates AI's adaptability in sustainability, safety, and efficiency, with a roadmap for future research.
[25]	Address growing interest in AI for construction via a workshop, covering design, safety, sustainability topics.	AI advances design, safety, sustainability; workshop fostered collaboration on real-world AI applications.	Highlights diverse AI applications and fosters industry-research collaboration for future construction.
[26]	Investigate AI and ML roles in enhancing construction processes and sustainable communities.	AI optimizes energy, air quality, waste; enhances planning, scheduling, facility management for sustainability.	Links AI to sustainable construction practices, predicting future trends in the built environment.
[27]	Review challenges and mitigation strategies for	39 challenges in 6 taxonomies (financial, technical, etc.); financial issues most	Provides a detailed taxonomy of BIM-AI

	integrating BIM and AI in construction projects.	significant; mitigation maps proposed.	challenges and actionable strategies for improved integration.
[28]	Discover technology opportunities between AI and construction using patent data and graph convolution networks.	Identifies convergence trends (e.g., computer vision with equipment); offers global/national strategic insights.	Introduces a novel method for identifying AI-construction convergence opportunities via patent analysis.
[29]	Review AI-IoT integration for environmental monitoring, focusing on water quality and climate data.	AI enhances precision, scalability in monitoring; challenges include data quality, security, interoperability.	Extends AI-IoT applications to construction-related environmental monitoring, highlighting future trends.
[30]	Review AI roles in construction engineering and management (CEM), identifying trends and future directions.	AI drives automation, risk mitigation, efficiency in CEM; future trends include robotics, AIoT, digital twins.	Comprehensive overview of AI in CEM, with key future directions for automation and intelligence.
[31]	Present methods for integrating AI into construction management for efficiency and cost savings.	AI improves planning, scheduling, safety; case studies show efficiency gains; challenges include data security, acceptance.	Offers practical AI integration methods and evidence of benefits, addressing adoption concerns.
[32]	Explore AI's influence on structural health monitoring (SHM) for infrastructure safety and maintenance.	AI advances data processing, anomaly detection, predictive maintenance in SHM; ethical issues noted.	Details AI's role in enhancing SHM, with focus on safety, efficiency, and future research needs.
[33]	Review AI applications in construction safety (text, vision, audio), identifying challenges and opportunities.	AI aids real-time monitoring, hazard detection; challenges include data quality, audio potential untapped.	Categorizes AI safety applications, advocating for integrated systems and responsible deployment.
[34]	Review AI in construction asset management, identifying applications, gaps, and trends.	AI applications in energy, condition, risk management; trends include digital twins, GANs, deep reinforcement learning.	First state-of-the-art on AI in asset management, identifying key trends for future research.
[35]	Conduct scientometric analysis of AI in construction, focusing on sustainability and project stages.	AI growth steady; ML, big data key; economic/governance pillars and design/construction phases show high AI potential.	Maps AI research evolution, linking it to sustainability and key construction phases.
[14]	Examine AI integration across construction phases for sustainable development goals (SDGs).	AI supports SDGs 7, 9, 11; ethical, data, training challenges noted; careful management needed.	Connects AI to specific SDGs, offering a sustainability-focused perspective on construction phases.
[5]	Identify AI opportunities and adoption challenges in construction using PRISMA review.	AI reduces time on repetitive tasks; fragmented industry hinders data acquisition/retention.	Highlights AI's planning benefits and data-related adoption challenges, increasing market acceptance insights.
[36]	Survey practitioners' perceptions of AI adoption in Korea's construction sector.	Positive outlook for AI post-2030; obstacles include data scarcity, skilled personnel shortage, legal gaps.	Provides practitioner insights into AI trends and policy needs for adoption in construction.
[37]	Identify issues in adopting AI in construction supply chains (CSCs) for sustainability.	17 issues; top 5 include trust, cybersecurity, cost; fuzzy DEMATEL prioritizes causal factors.	Novel prioritization of AI adoption issues in CSCs, aiding sustainable supply chain management.
[38]	Review AI advances in structural health monitoring (SHM) for civil infrastructure.	AI improves accuracy, predictive maintenance; vision-based methods expand scope; scalability challenges remain.	Traces AI evolution in SHM, emphasizing precision and future

			integration challenges.
[39]	Identify barriers to adopting digital technologies for circular economy (CE) in construction.	37 barriers in 9 categories; 19 critical (e.g., organizational, investment); CE integration hindered.	Comprehensive barrier analysis for digital tech in CE, aiding practitioners and policymakers.
[40]	Review AI and cloud computing in construction, identifying hotspots and gaps.	Hotspots: project performance, quality/safety, energy efficiency; gaps in real-time safety, ethics noted.	Identifies key AI-cloud applications and research gaps, laying a foundation for future construction tech.
[41]	Evaluate AI's role in advancing construction materials under Industry 4.0 framework.	AI enhances durability, sustainability of materials; envisions intelligent design and operations.	Links AI to material innovation, proposing a revolutionary Industry 4.0 integration pathway.
[42]	Model the relation between AI-based drones and sustainable construction project success.	Privacy, legal, economic barriers hinder drone adoption; benefits include safety, quality, sustainability gains.	Demonstrates AI drones' impact on project success, urging legal and HR solutions for adoption.
[43]	Review AI's roles in civil engineering lifecycle (design, management, SHM, smart cities).	AI optimizes design, management, SHM; challenges include legacy integration, privacy, scalability.	Comprehensive AI lifecycle review, highlighting interdisciplinary potential and future trends.
[44]	Summarize AI progress in civil engineering across design, construction, and inspection.	AI enhances design, damage recognition, disaster evaluation; merges data with physical laws for innovation.	Advances understanding of AI's broad CE applications, proposing intelligent science integration.
[13]	Review machine learning evolution and applications in construction, foreseeing future directions.	ML aids supervision, detection, maintenance; data acquisition challenges persist; deep learning potential noted.	Traces ML development, offering suggestions for construction-specific deep network models.
[45]	Examine AI advancements in construction management over 5 years, focusing on efficiency.	AI improves equipment, safety, cost management; emerging themes identified; future trends in analytics, safety systems.	Synthesizes recent AI-CM progress, outlining key gaps and future innovation directions.

As presented in Table II, 32 papers were included in this review after a thorough search of literature using the inclusion and exclusion criteria presented in Table I. Out of the 32 papers included for this review, 29 are journal articles while 3 were conference papers. All were accessible and written in English Language. The studies are predominantly peer-reviewed journals and provide a robust evidence base, with conference proceedings adding diverse perspectives on emerging trends and views, collectively underscoring AI's potential to modernize construction despite adoption barriers.

III. Findings

The findings of this review are presented in this section. These findings are presented based on the objectives of the review

A. *Opportunities of AI in the Construction Industry*

The findings of this objective are presented in Table III

TABLE III. Opportunities of AI in the Construction Industry

Findings	**Authors Supporting**	**Description**
Automation of repetitive tasks increases productivity and reduces labor costs.	[5], [9], [13], [19], [30]	AI technologies like ML and computer vision automate site supervision, detection, and maintenance, improving efficiency and forecasting accuracy.
Optimization of construction processes and materials enhances efficiency and sustainability.	[14], [19], [24], [26], [41]	AI optimizes project completion times and develops durable, recyclable materials, aligning with sustainability goals and reducing resource waste.
Integration with Industry 4.0 enables smart buildings and advanced analytics for project performance.	[28], [32], [34], [40], [41]	AI with Industry 4.0 improves material durability, energy efficiency, and predictive maintenance, creating adaptive, sustainable structures.

The application of artificial intelligence (AI) in the construction industry as shown in Table III presents several key opportunities that can significantly enhance efficiency, innovation, and sustainability.

1) Automation of repetitive tasks

One of the primary opportunities is the automation of repetitive tasks, which can lead to increased productivity and reduced labor costs. AI technologies, such as machine learning can recognize patterns from data to make intelligent decisions [46], [47], [48]. Also, computer vision enable the automation of site supervision, automatic detection, and intelligent maintenance, thereby optimizing the construction processes and improving project outcomes [5], [13], [30]. AI technology streamlines repetitive jobs boosting productivity and enabling more precise predictions of events, risks, and expenses when planning construction projects [5].

2) Optimization of Construction Process

The application of AI technology enables better construction operations and project duration prediction [19]. Through machine learning algorithms developers can produce materials which combine extended lifespan with environmental friendliness and improved safety features and recyclability. The concept aligns with Industry 4.0's objective to develop manufacturing systems that become smarter and more productive [41]. Studies also further highlights that AI integration with digital technology has the potential to create an innovative future where building materials and methods function optimally while maintaining environmental sustainability [49], [50], [51]. The system enables companies to improve operational efficiency while optimizing resource utilization and minimizing project delays.

3) Integration of AI with Industry 4.0

AI's merger with Industry 4.0 tech has an impact on the creation of cutting-edge building materials. This makes them last longer, stay eco-friendly, and easier to recycle [41]. This combination can result in smarter ways to use and run buildings, which fits with what Industry 4.0 aims to do [41]. AI-driven data analytics has an impact on the performance of construction projects. It delivers data on project indicators, quality control, and energy efficiency [40].With such collaboration, intelligent buildings that respond to environmental conditions and user needs can be developed. Such buildings optimize the use of resources and minimize operating costs in the long run. For instance, AI has the ability to analyze real-time sensor data on materials to predict when maintenance will be required needs [32]. This makes the structures last longer and minimizes waste. Secondly, employing AI in managing building assets can make energy management, condition assessment, and risk management better. This results in sustainable construction practices [28], [34].

Nonetheless bringing AI into the construction industry isn't easy. The industry's scattered nature makes it hard to get and keep data. This data is key for AI technologies to work well [5]. In addition, construction sites are complex. This makes it tough to get labeled data needed to train machine learning models. As a result, it's harder to develop and roll out AI solutions [13].
The combination of AI with construction technologies has very promising prospects for new ideas notwithstanding these challenges. AI can provide industry regulators and stakeholders with well-informed decisions through offering essential insights into possibilities for technology throughout the world and in particular countries [28]. The application of AI in construction offers many chances to enhance productivity, stimulate innovation, and support sustainability. Even as problems in the handling of data and dispersal of industry are still pending, the potential of gains on deployment of AI are vast. There can be great strides on handling projects of maximal utilization of material and minimizing one's imprint upon the natural environment by using their solutions in meeting these needs.

B. Challenges and Limitations in AI Adoption in the Construction Industry

The findings on the challenges of AI adoption in the construction industry are presented in Table IV.

TABLE IV. CHALLENGES AND LIMITATIONS IN AI ADOPTION

Findings	**Authors Supporting**	**Description**
Fragmented industry structure hinders data acquisition and standardization.	[5], [21], [23], [27], [37]	Multiple stakeholders and inconsistent systems lead to poor data retention and interoperability, limiting AI effectiveness.
Economic and financial constraints deter AI investment due to high costs and uncertain ROI.	[23], [27], [35], [37], [39]	High initial costs for AI and BIM integration, coupled with a focus on short-term gains, discourage adoption despite long-term benefits.
Technical and data challenges limit AI model development and deployment.	[13], [17], [20], [33], [36]d	Scarcity of high-quality, labeled data and lack of infrastructure or expertise impede sophisticated AI applications like real-time monitoring.
Legal and regulatory barriers create uncertainty around privacy and compliance.	[22], [29], [36], [42], [43]	Lack of clear frameworks for data security and AI use complicates adoption, requiring standardized regulations for ethical implementation.
Organizational and cultural resistance slows AI integration due to traditional practices.	[14], [20], [22], [31], [45]	Conservative industry norms, lack of awareness, and fears of job displacement hinder acceptance; training and cultural shifts are needed.

As presented in Table IV, the adoption of AI in the construction industry is hindered by a range of challenges, including the fragmented nature of the industry, economic constraints, technical and data challenges, legal and regulatory barriers, and organizational resistance. By tackling these barriers, the construction industry can harness the full potential of AI technologies to improve efficiency, sustainability, and project success.

1) Fragmented Nature of the Industry

One of the primary challenges hindering the adoption of AI in the construction industry is its fragmented nature [37], [52]. This fragmentation leads to significant issues in data acquisition and retention, which are critical for effective AI implementation. The construction industry faces a big problem. It is full of different groups each with their own ways of doing things. This makes it hard to collect and share data in a standard way [5]. When data isn't consistent, it's tough to use AI tools well [23].

The industry's fragmented nature doesn't just make data management tricky. It also makes it hard to use AI systems across different parts of construction projects. Without a single way to handle data and make sure it's always available, AI systems can't work their best [21]. This leads to waste and less effective work. To fix this, the whole industry needs to work together. There is need to set up standard ways to handle data and make different systems work better together [27].

2) Economic and Financial Constraints

Money issues are another big roadblock to using AI in construction [37], [39]. This happens because AI tech costs a lot to start with, and it's not clear if it'll pay off, which scares many companies away from putting money into these new ideas. Both builders and clients have money concerns that make them hesitant [23]. Money related challenges are tough when it comes to mixing AI with Building Information Modelling (BIM) where setting it up and keeping it running can be too expensive for many [27]. Data acquisition and training of AI algorithm are also money consuming [35].

Money problems get worse because the industry practitioners try to cut costs and make quick profits. This often means not putting enough money into new technologies like AI. To fix this, builders need to start thinking about long-term benefits and sustainability.

3) Technical and Data Challenges

Big technical problems, like needing good data management and advanced algorithms, make it hard to use AI [17]. The building industry often doesn't have the right setup to use complex AI tools, like watching things in real-time and spotting dangers [33]. Additionally, the absence of enough quality training data for construction alone makes the development and deployment of AI models with satisfactory performance challenging [36]. The technical challenges show that the industry is in need of special training and experience in AI technology. Without having staff who are experienced in managing and installing AI systems, constructors are unable to obtain all the useful things the tools can offer. There is a need to invest in training and teaching to develop a workforce that can use AI technology if constructors are to break these technical barriers [22].

4) Legal and Regulatory Barriers

Legal and regulatory issues also create major roadblocks for AI use in construction. Concerns about keeping personal info safe and the lack of clear rules for AI applications create uncertainty and slow down the adoption of AI tech [42]. The absence of standard guidelines for AI use in construction makes things even more complex, as companies aren't sure what they need to do to follow the rules [36]. This highlights the need to establish clear legal frameworks. Doing so will give companies more certainty and confidence and make sure AI is used in a responsible and ethical way.

5) Organizational and Cultural Resistance

Organizational and cultural resistance to change is also one of the principal barriers to the adoption of AI. The building construction industry is conservative in nature, with strong reliance on established and proven conventional methods [22] that may lead to resistance to the uptake of, or lagged uptake of new technologies. This resistance to adopt stems from not being familiar with it or not understanding or knowing how AI could help, and fear of losing jobs [20]. To tackle these issues, builders need a smart plan. This means showing people how AI can help, giving them training to help to make the switch easier, and getting workers involved in bringing in AI to cut down on fears and pushbacks. Creating a workplace that values new ideas and always trying to get better can also help knock down these barriers.

C. The Role of Emerging AI Tools In Shaping The Future of Construction Practices

The findings on the role of AI tools in Shaping the future practices are presented in Table V.

TABLE V. CHALLENGES AND LIMITATIONS IN AI ADOPTION

Findings	**Authors Supporting**	**Description**
AI enhances construction management through predictive tools for scheduling, cost, and safety.	[9], [24], [26], [30], [31], [35], [43], [45]	ML and DL predict risks, optimize timelines, and improve safety, enabling proactive management and setting new standards for precision.
Generative design and optimization revolutionize architectural design and resource use.	[17], [25], [34], [43], [44]	AI explores design possibilities, minimizes waste, and supports sustainable practices, enhancing creativity and efficiency in design processes.
Structural health monitoring (SHM) improves safety and durability with real-time analytics.	[25], [32], [38], [43], [44]	AI processes sensor data for fault detection and predictive maintenance, enhancing infrastructure resilience and worker safety on-site.
Sustainability is advanced through energy optimization and environmental monitoring.	[14], [25], [26], [29], [35], [40]	AI reduces environmental impact via energy management, waste reduction, and IoT integration

As presented in Table V, AI is increasingly being recognized as a transformative force in the construction industry, offering numerous opportunities to enhance efficiency, sustainability, and innovation. The integration of AI into construction practices is reshaping traditional methods and introducing new paradigms for project management, design, and execution. This section presents the findings on the role of emerging AI tools in shaping the future of construction practices.

1) Enhancing Construction Management

AI has a big impact on construction management. It makes scheduling, cost control, and safety checks better [31]. AI tools help complete projects on time and within budget. This boosts productivity and cuts down on delays and overspending [30], [43], [45]. Machine learning and deep learning are great at telling project results and spotting possible risks [24], [26], [35]. This lets managers take action before problems happen. They can see issues coming, like failure of equipment, worker disputes [26], or bad weather [9]. This means engineers can change plans immediately to avoid trouble. These upgrades to construction management don't just make projects more likely to succeed. They also set a new bar for accuracy and responsibility in the field.

2) Design Optimization and Innovation

AI is causing a revolution in architectural design. It allows for design processes that create many different possibilities. These processes improve things like how materials are used, how strong structures are and how good they look [25], [44]. AI helps the industry move towards a circular economy. It does this by using materials in the best way possible, which leads to less waste. This means building projects have less impact on the environment. AI can also make site planning and layout better on its own [25]. This means space and resources are used more effectively. These advances boost creativity in construction and make building practices more sustainable and cost-effective [43]. This shift allows architects to push past old boundaries. They can now test out thousands of design choices to find answers that strike a balance between how well something works and how it affects the world around it. For an example, AI can model how different designs would work in different conditions to ensure buildings are efficient.

3) Structural Health Monitoring and Safety

AI for structural health monitoring (SHM) improves the lifespan and safety of infrastructure [32], [38]. AI algorithms help diagnose faults and quantify health [43], [44], enabling maintenance and repair on a timely basis. This is because AI can process huge volumes of sensor data from structures [32], including bridges, buildings, and tunnels, to detect small issues like cracks, rust, or stress points that are easy to miss using conventional methods. Machine learning models can be programmed with historical data to predict how structures will degenerate over time [53], [54]. This helps engineers correct problems before they escalate. AI technology also keeps building construction sites safe in real-time. It uses data analysis to identify potential hazards and prevent accidents [25]. This preventive safety management measure is vital in risk reduction and maintaining the health of workers.

4) Sustainability and Environmental Impact

AI plays a significant role in enhancing the construction industry's sustainability. It helps to minimize the environmental footprint of construction projects by increasing the effectiveness of energy use and waste management [14], [26], [35]. This is due to the fact that AI use in green building construction and design has the ability to make the most out of scarce resources [5], [25], and foster eco-friendliness. When AI teams up with Internet of Things (IoT) technology, it gets even better at watching and fine-tuning environmental performance as it happens [29]. Even though these opportunities look good, bringing AI into construction has its fair share of hurdles. People worry about keeping data safe and private, and these concerns need to be sorted out for more to get on board with AI tech. As experts keep digging into this field and coming up with new ideas, AI is set to push the construction industry towards a future that's both greener and more high-tech.

IV. Conclusion

This systematic review shows that AI has a revolutionary impact on the construction industry. It boosts efficiency, sparks new ideas, and promotes sustainability. AI creates key opportunities. It automates repetitive work, which increases productivity and cuts labor costs. This happens through technologies like machine learning and computer vision, as can be seen in site supervision and predictive maintenance. AI also improves construction processes, from making materials to planning projects. This aligns with Industry 4.0 goals to create long-lasting, eco-friendly, and reusable materials. Moreover, AI-powered tools enhance construction management, design innovation, and structural health monitoring. This allows for proactive risk management generative design, and real-time safety improvements. Together, these advances cut delays, lower costs, and encourage green practices. This makes AI a key part of modernizing the industry. However, realizing these benefits requires addressing significant challenges. A major obstacle is the fragmented nature of the industry, which hampers data acquisition and standardization—both of which are essential for the effective deployment of AI.

Despite its transformative potential, artificial intelligence (AI) faces significant challenges in the construction industry. These challenges include financial constraints, technological limitations, ambiguous legal frameworks, and organizational resistance to change. Addressing these barriers is essential to fully leverage AI's capabilities. The fragmented nature of the construction sector complicates efforts to maintain consistent and reliable data. Furthermore, the high cost of AI implementation and a shortage of skilled professionals hinder widespread adoption. Regulatory gaps and a traditionally conservative industry culture further impede integration.

Nevertheless, the convergence of AI with emerging technologies such as generative design, Building Information Modeling (BIM), and the Internet of Things (IoT) presents a promising outlook. This synergy enables the development of smarter buildings, safer infrastructure, and more environmentally sustainable practices. To capitalize on these opportunities, stakeholders must collaborate, invest in workforce development, and establish standardized protocols for data management and regulatory compliance. Overcoming these obstacles will allow the construction industry to enhance efficiency, promote sustainability, and drive innovation, laying the foundation for a technologically advanced built environment.

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