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Artificial intelligence and sustainable development goals: Systematic literature review of the construction industry

Massimo Regona, Tan Yigitcanlar *, Carol Hon, Melissa Teo

City 4.0 Lab, School of Architecture and Built Environment, Queensland University of Technology, 2 George Street, Brisbane, QLD 4000, Australia

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ABSTRACT

While acknowledging the widespread recognition of artificial intelligence's (AI) potential in achieving sustainable development, there remains a notable deficiency and thorough examination of its specific applications, impacts, and challenges, particularly within the construction industry. A comprehensive investigation is critical to explore and understand the multifaceted applications of AI in fostering sustainability across all phases of a construction project. This paper aims to examine how AI can be effectively integrated across the key project phases—i.e., planning, design, construction, and operation and maintenance, through a systematic literature review to map AI applications, their impacts, adoption challenges, and best practices. The findings revealed: (a) Sustainable development goals (SDGs) pertinent to the construction industry—i.e., SDGs 6-9,11-13,15,17; (b) SDGs that show the highest potential to promote sustainability within the construction industry—i.e., SDGs 7,9,11; (c) Within the spectrum of these goals, AI can potentially transform the construction industry and contribute to the sustainability consideration processes in a more efficient and resilient ways; (d) Ethical considerations, data privacy and security concerns must be addressed, along with an urgent need for specialised training and maintenance of these AI systems; (e) Careful AI implementation and management is essential to harness its full potential, while addressing adoption challenges within the construction sector.

1. Introduction

In recent years, the construction industry has experienced a transformative shift due to the progression of artificial intelligence (AI) technologies (Li et al., 2021). This shift has been characterised by a fundamental redirection in how construction processes are design, planned, and executed (Wang et al., 2023). AI's integration has transformed current practices, introducing innovative methodologies and tools that optimise various facets of the construction lifecycle. For instance, AI-powered drones are being used for site surveying and progress monitoring. These drones can quickly and accurately capture data, allowing stakeholders to identify potential issues and make informed decision in real time. It has empowered the industry with predictive analytics, automation, and data-driven insights that streamline workflows, enhance decision-making, and improve overall project outcomes (Pan et al., 2021).

The 2015 introduction of the United Nations' 2030 Agenda prompted a strategic shift within the construction industry (General, 2015). This shift occurred because the construction industry impacts various dimensions of society, economy, and environment, rendering it a crucial contributor to the realisation of sustainable development goals (SDGs). In shaping the built environment, the industry affects communities, making its role indispensable in advancing the global sustainability agenda outlined by the SDGs (Pan et al., 2023). The industry is progressively embracing sustainability principles influenced by the SDGs by incorporating sustainable design, adopting green building standards, concentrating on sustainable materials and technologies, highlighting lifecycle assessment, forging collaborative partnerships, and investing in research and innovation. This alignment with the SDGs is driving the industry towards a more environmentally friendly and inclusive future, with stakeholders throughout the value chain collaborating to accomplish SDGs on a global scale (Bang et al., 2022).

Moreover, the construction industry is undergoing a significant transformation, acknowledging the imperative to incorporate AI as an essential tool in daily operations (Regona et al., 2022a). AI's crucial role is evident in its ability to optimise building designs for enhanced energy efficiency and minimised environmental impact. Through extensive data analysis and scenario simulations, AI empowers architects and

* Corresponding author.
E-mail address: tan.yigitcanlar@qut.edu.au (T. Yigitcanlar).

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engineers to make well-informed decisions that comply with rigorous green building standards. In addition to promoting sustainability, AI has played a pivotal role in advancing construction materials and technologies, driving innovation and resilience in structural design (Omer, 2020). By harnessing AI algorithms and machine learning techniques, researchers and industry professionals have developed novel materials that enhance the durability, safety, and efficiency of structures. These advancements not only contribute to sustainable construction practices but also address evolving challenges in urbanisation, climate change, and infrastructure development (Yigitcanlar et al., 2008).

The construction industry is beginning to realise the advantages of sustainable construction practices and technological advancements into their traditional frameworks (Wang et al., 2021). This shift signifies a broader recognition of the imperative to mitigate environmental impact and enhance long-term sustainability across all facets of construction activity. As awareness grows regarding the potential advantages of sustainable approaches, stakeholders within the industry are increasingly exploring innovative solutions and integrating them into their established practices (Baduge et al., 2022). This evolution reflects a proactive response to emerging global challenges such as, resource depletion, cost overruns, safety issues and urbanisation pressures, signalling a pivotal moment in the industry's journey towards greater resilience and responsibility (Akinosho et al., 2020).

AI presents itself as a compelling pathway for the construction sector to attain sustainable goals by harnessing its capacity to process vast datasets, anticipate outcomes, and automate tasks. These capabilities serve as a catalyst for driving sustainable practices within construction. Evident by its ability to optimise energy usage in building designs, minimise waste through accurate resource allocation, enhance safety measures by pre-emptively identifying risks, streamline project management for efficiency, ensure real-time compliance with sustainability standards through monitoring, and enable life-cycle assessments for eco-friendly materials (Zhang, 2021). These AI-driven tools not only streamline operations but also form the bedrock for advancing the industry's sustainability journey.

Despite extensive research on SDGs, a significant research gap exists regarding the construction industry's role in achieving them, particularly concerning AI implementation (Sachs et al., 2019). While the industry is vital for sustainability, empirical studies on its contribution to SDGs are limited. This gap highlights the need for focused investigation into aligning construction practices and AI technologies with SDGs to advance global sustainable development (Çetin et al., 2021). The intersection of AI, sustainability, and construction remains underexplored, with minimal empirical research on AI's practical applications in enhancing sustainability outcomes in construction projects. Additionally, as AI evolves and becomes more prevalent in construction projects, understanding its coexistence with sustainability is crucial. Existing literature provides theoretical frameworks for addressing broader sustainability aspects of construction projects, but limited sources explore how AI can aid the construction industry in achieving relevant SDGs. This scarcity underscores the need for further exploration and analysis to fully harness AI's potential as a catalyst for sustainable advancements within construction practices (Saeed et al., 2022).

Bridging this gap requires interdisciplinary collaboration to develop holistic approaches for integrating AI into construction practices. Empirical studies are necessary to identify barriers and opportunities associated with AI adoption in construction, including data privacy, technical challenges, and workforce readiness. Addressing the research gap is crucial for informing policy decisions and industry practices to achieve sustainable development goals effectively. Closing this gap can unlock the construction industry's full potential in advancing sustainability and contributing to SDGs.

This study aims to comprehensively explore the intersection of technological innovation, particularly AI, with sustainable construction practices. The objective is to elucidate the role of AI in enhancing sustainability across various phases of construction projects, thereby contributing to the achievement of SDGs. Through an in-depth analysis, the study seeks to identify opportunities and challenges associated with integrating AI-driven solutions in construction processes. Additionally, it aims to provide actionable insights for industry stakeholders on optimal ways of leveraging AI to achieve sustainability outcomes, improve project efficiency, and foster responsible practices within the construction sector.

The paper is organised into several sections to provide a structured analysis of the research findings. In Section 3, the research methodology employed in this study is outlined, detailing the systematic approach adopted to conduct the literature review and map AI applications in the construction industry. Section 4 presents the results and general observations regarding the relevant SDGs in construction, clarifying how AI can contribute to achieving these goals effectively. This section provides a comprehensive overview of the direct and indirect impact of AI on a construction project. In Section 5, a detailed discussion of the results is offered, providing deeper insights and interpretations into the implications of AI integration for sustainability in the construction sector. Finally, Section 6 concludes the paper by summarising the key findings, discussing their implications for future research and practice, and suggesting potential avenues for further exploration.

2. Literature background

2.1. Sustainable construction

At the inaugural First International Conference on Sustainable Construction in November 1994, the concept of sustainability was defined as follows: "Building a healthy built environment through the application of resource-efficient, ecologically sound principles (Poprach et al., 2019)". Sustainable construction represents a commitment to three fundamental pillars:

- Economic sustainability involves enhancing profitability by optimising the utilisation of resources, including labour, materials, water, and energy (Oluleye et al., 2022).
- Environmental sustainability entails preventing harmful and potentially irreversible effects on the environment through prudent use of natural resources, minimising waste generation, and safeguarding (Barros et al., 2021).
- Social sustainability encompasses meeting the needs of individuals throughout the construction process, from inception to demolition, by ensuring high customer satisfaction and fostering close collaboration with project related stakeholders (Fnais et al., 2022).

In traditional design and construction, the focus is on cost, performance, and quality objectives (Opoku et al., 2019). However, sustainable design and construction bring in additional considerations, such as minimising resource depletion, reducing environmental degradation, and promoting a healthy built environment. This shift towards sustainability marks a new era within the building design and construction industry, where sustainable goals are embedded in decision-making processes throughout the lifecycle of the facility. Fig. 1 outlines the evolution and challenges of the sustainable construction concept in a global context.

In contrast to many other industries, the construction sector in Australia holds a unique position due to its enduring nature and profound, long-lasting impact on society. Buildings and infrastructure developed within this industry can shape communities and landscapes for generations, emphasising the critical importance of thoughtful planning and design (Barbosa Júnior et al., 2023). The decisions made during the initial phases of a construction project have far-reaching implications for its sustainable performance over time.

For a structure to achieve exemplary performance while minimising its ecological footprint, it is imperative to embed sustainability principles from the outset of the project. This proactive approach ensures that

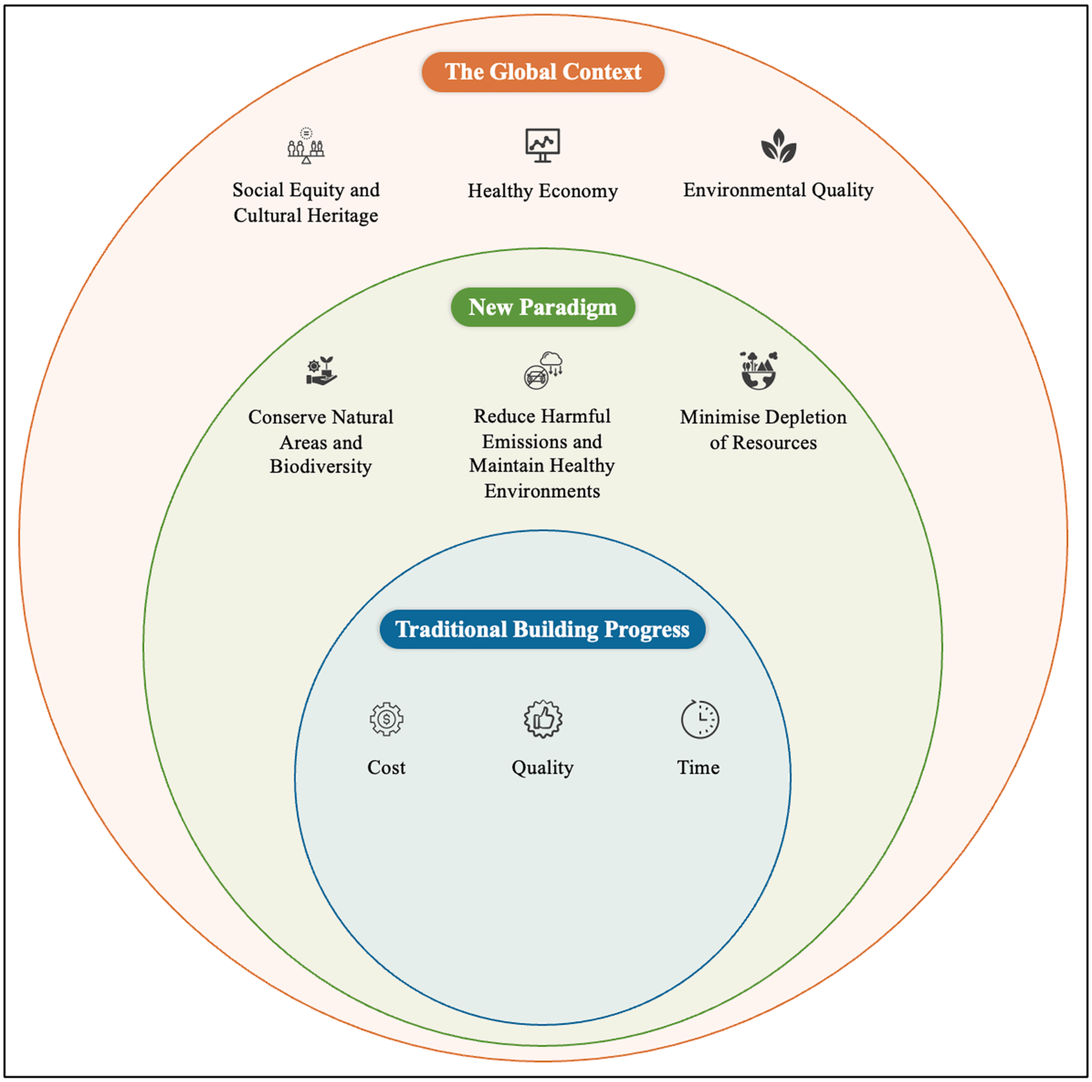

Fig. 1. Challenges of sustainable construction in a global context.

considerations of environmental, economic, and social sustainability are integrated seamlessly into every stage of development and construction. As highlighted by Regona et al. (2022b), the early incorporation of sustainability principles is fundamental to realising a built environment that not only meets the needs of the present but also safeguards the well-being of future generations. Harmonising the diverse facets of sustainability is essential in achieving sustainable construction practices. This entails not only minimising environmental impact but also fostering economic viability and social equity (Boje et al., 2020). Table 1 illustrates the multifaceted nature of sustainability, emphasising the interconnectedness of environmental, economic, and social considerations in construction projects. By embracing this holistic approach, stakeholders can create buildings and infrastructure that not only endure but also contribute positively to the well-being of society and the planet (Gao et al., 2020).

Drivers for sustainable construction encompass a diverse range of factors that guide the industry towards sustainable beneficial practices (Fayek, 2020). These drivers include regulatory frameworks mandating green building standards and emissions reduction targets, increasing consumer demand for eco-friendly and energy-efficient buildings, financial incentives such as tax breaks and subsidies for sustainable projects, innovative technologies and materials that enhance efficiency and minimise environmental impact, as well as broader societal trends emphasising corporate social responsibility, safety, well-being of project

Table 1
Principles of sustainable construction, derived from Chen et al. (2022).

Sustainability Pillar	Description
Environmental	• Decrease material intensity through substitution technologies • Improve material recyclability • Minimise and regulate the usage and spread of harmful materials • Lower the energy needed for processing goods and delivering services • Back international conventions and agreements • Optimise the sustainable utilisation of biological and renewable resources • Consider the effects of planned projects on air, soil, water, flora, and fauna.
Social	• Encourage community involvement • Foster the establishment of suitable institutional structures • Evaluate the influence on the current social context • Assess the effects on health and overall well-being
Economic	• Incorporate external costs • Explore alternative financing methods • Create suitable economic tools to encourage sustainable consumption • Evaluate the economic impact on local structures

stakeholders and long-term viability in their projects and operations (Pizzi et al., 2020).

Challenges in sustainable construction pose substantial barriers to the broad acceptance of sustainable practices due to several factors. These include the considerable upfront expenses linked to green building materials and technologies, a shortage of skilled labour and proficiency in sustainable construction techniques, complex and inconsistent regulations that hinder adherence to green building criteria, perceived risks and uncertainties regarding the effectiveness and durability of sustainable designs and technologies, and entrenched industry attitudes and practices that favour traditional construction methods. (Fnais et al., 2022).

Additionally, financing constraints, market barriers, and insufficient awareness or understanding of the benefits of sustainable construction amongst stakeholders further hinder progress towards a more sustainable built environment. Overcoming these barriers requires concerted efforts from governments, industry stakeholders, and the broader community to address policy gaps, promote innovation, provide financial incentives, and foster collaboration towards achieving sustainable development goals.

Significant opportunities remain for projects to become more sustainable for the entirety of the building lifecycle (Regona et al., 2023). While there are variations from previous studies that investigated the environmental consequences of construction, there appears to be a broad consensus on the need for significant transformation in the industry to embrace sustainability goals and contribute to sustainable development (Wang et al., 2023).

2.2. Sustainable development goals in construction

SDGs emerged as an outcome of the Rio United Nations Summit in 2013 (Fang et al., 2021). The summit concluded by recognising the need to establish global development guidelines that consider human needs, environmental sustainability, human rights, and partnerships (Ma et al., 2019). The 17 goals and their 169 targets are structured around the three sustainability pillars – social, environmental, and economic, as seen in Fig. 2. Unlike the Millennium Development Goals (MDG) predecessor, the SDGs offer better coverage and balance between economic, social, and environmental dimensions of sustainable development (Columbus, 2017).

SDGs represents a comprehensive framework for addressing social, economic, and environmental challenges through predefined targets and indicators (Hovnanian et al., 2019). The construction industry has a direct impact on several crucial SDGs, namely SDG 6-9, SDG 11-13, SDG 15, and SDG 17, as illustrated in Fig. 3. SDG 6, which focuses on clean water and sanitation, is affected by construction projects that can alter water resources and contribute to the development of water infrastructure. SDG 7, concerning affordable and clean energy, intersects with construction through energy consumption and sustainable practices. SDG 8, addressing decent work and economic growth, is influenced by the construction sector's job opportunities and labour practices. SDG 9, emphasising industry, innovation, and infrastructure, is closely tied to construction's role in developing infrastructure and driving economic growth. Additionally, SDGs 11 to 13, which focus on sustainable cities and communities, responsible consumption and production, and climate action, are significantly impacted by the construction sector. SDG 11 highlights the critical role of the construction industry in urban development and promoting resilient urban spaces.

Furthermore, SDG 12 emphasises resource efficiency and waste reduction through sustainable construction practices such as using recycled materials, minimising waste generation, and promoting circular economy principles. Additionally, SDG 13 underscores the urgent need to adopt low-carbon building materials, energy-efficient design strategies, and climate-resilient infrastructure. Moreover, SDG 15, which addresses life on land, is closely linked to construction practices, particularly concerning land use and biodiversity conservation. Lastly,

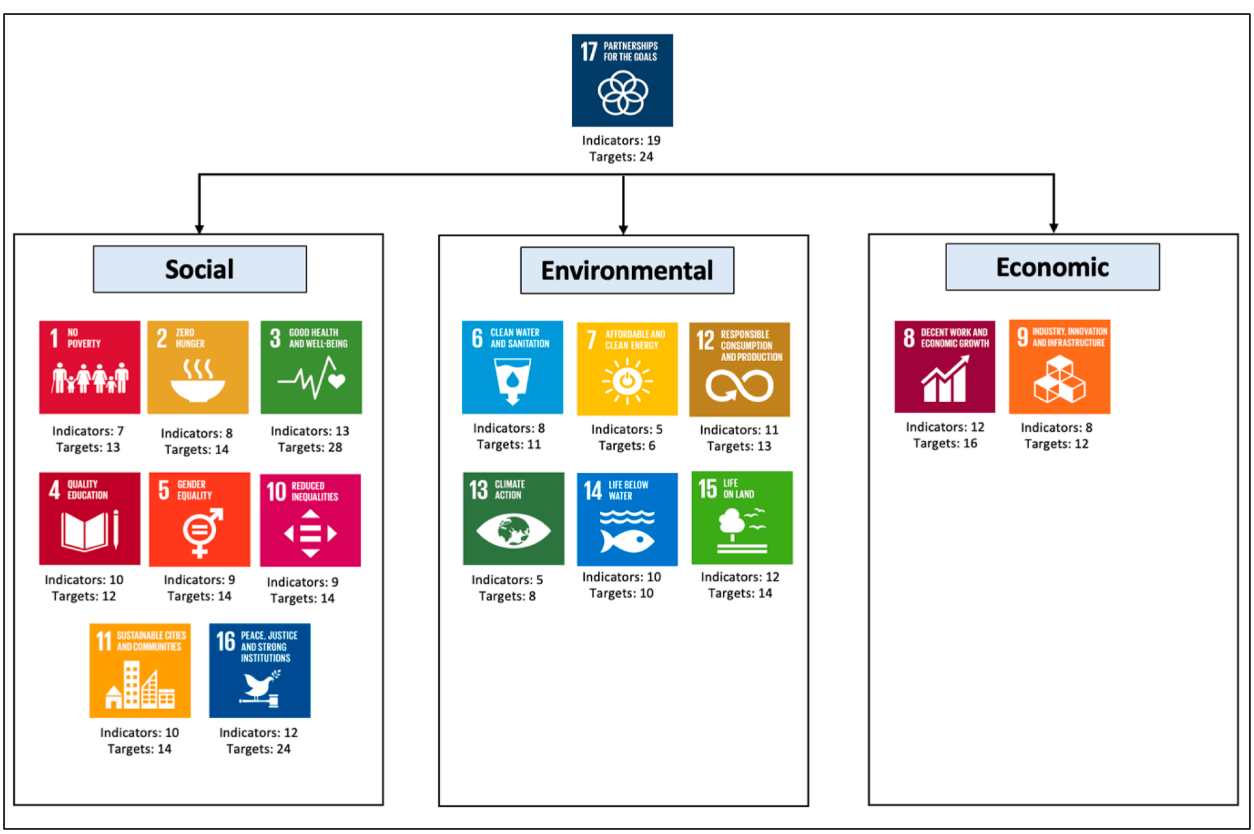

Fig. 2. Sustainable development goals, targets and indicators derived from United Nations (2015).

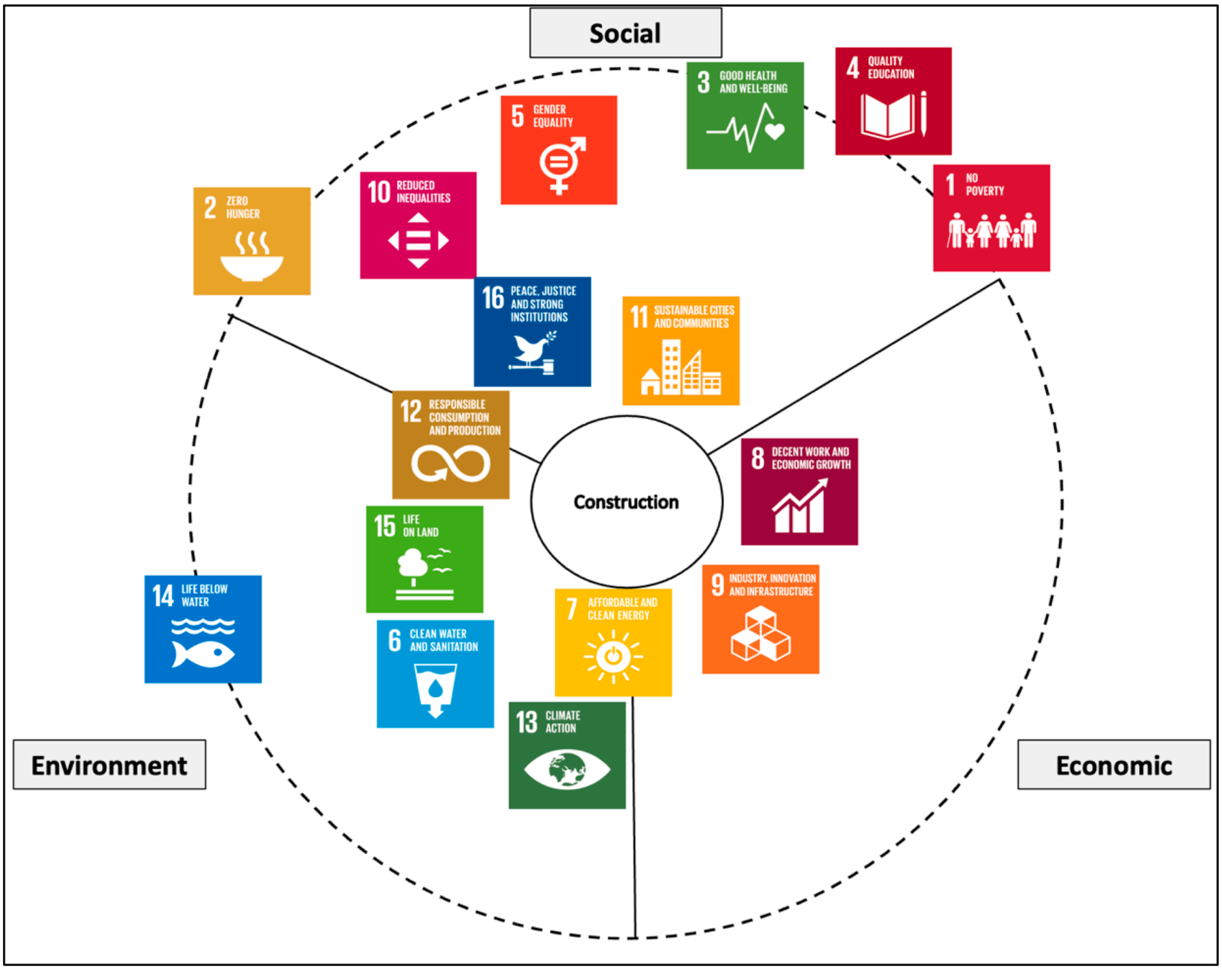

Fig. 3. SDGs based on the three pillars of sustainability.

SDG 17, which emphasises partnerships for all 16 goals, underscores the collaborative efforts required between various stakeholders within the construction industry and beyond to achieve sustainable development objectives. These findings highlight the essential role of the construction industry in advancing SDGs and actively contributing to the global sustainability agenda.

While the SDGs are often portrayed as distinct and separate objectives, they are intricately interconnected rather than isolated. This interdependence provides a route for crafting strategic policies and solutions that simultaneously address multiple goals (Nilsson et al., 2016). This integrated framework implies that advancements in one target can lead to diverse impacts that influence other targets. Consequently, this raises the potential for unintended consequences arising from trade-offs between goals if policies and actions lack careful planning.

Implementing SDGs' principles in a project presents the construction industry with an opportunity to broaden its focus beyond environmental sustainability. However, achieving these goals isn't solely the responsibility of governments and policymakers; it requires collaborative efforts from various sectors to embed sustainability principles into their practices (Waage et al., 2015). To meet the SDGs by the 2030 deadline, it's crucial for all levels of government and sectors of society to integrate these goals into local planning schemes. Local governments have a vital role here, as they can embrace the inclusive nature of the SDGs and identify sectors that may need extra support (Pizzi et al., 2020).

Therefore, successful implementation relies on effective communication between government, private, and public sectors to come to agreements. By fostering partnerships and facilitating dialogue amongst stakeholders, the construction industry can contribute significantly to advancing the SDGs and promoting sustainable development (Rakesh et al., 2023). This collaborative approach not only enhances our ability to address societal and environmental challenges, but also fosters a culture of shared responsibility and innovation essential for lasting impact.

2.3. *Artificial intelligence in construction*

AI is rapidly becoming a cornerstone in the construction industry, reshaping the entire project lifecycle from the design, construction, to the repair and maintenance stage. This transformative evolution is marked by the integration of AI-powered solutions that leverage data analytics, automation, and sophisticated algorithms to optimise every aspect of construction projects (Turner et al., 2020).

While many definitions exist for AI, it is widely acknowledged that AI within the built environment involves "the creation of intelligent machines and software that emulate cognitive systems for learning and problem-solving" (Baum et al., 2017). AI is a broad field of computer science that focuses on creating systems or machines capable of performing tasks that typically require human intelligence. The following are the three subsets of AI:

- Artificial Intelligence (AI): The broad field of computer science focused on creating intelligent systems capable of tasks requiring human-like intelligence (Baduge et al., 2022).
- Machine Learning (ML): A subset of AI that develops algorithms enabling computers to learn from data and improve performance without explicit programming (Bang et al., 2022).

- Deep Learning (DL): A subset of ML that automatically employs deep neural networks to learn and represent complex patterns, revolutionising AI applications like image recognition and natural language processing (Baduge et al., 2022).

These AI subcategories have garnered increased interest due to notable progress in data collection and consolidation, analytical capabilities, and the availability of adequate computing power. This is evident as the construction industry spent USD 26 billion on engineering and construction technologies from 2014 to 2019, an increase of USD 8 billion over the previous five years (Young et al., 2021).

In recent years, the construction industry has begun to embrace technology as firms recognise the benefits and operational advantages it offers (Regona et al., 2023). This shift reflects a growing awareness amongst industry stakeholders of the transformative potential of technological integration in improving project outcomes and enhancing overall productivity. The adoption of technology in construction holds promise for addressing key challenges faced by the urban built environment, including safety concerns, labour shortages, and cost and schedule overruns (Yun et al., 2016). By leveraging innovative technologies, construction companies can navigate these challenges more effectively while also unlocking new opportunities for efficiency and innovation.

Tables 2 and 3 provide comprehensive insights into the potential and future real-time and technical applications of AI within the construction industry. The two tables outline the diverse ways in which AI-driven solutions are being deployed to optimise various aspects of construction projects, from real-time monitoring and predictive analytics to advanced automation and decision support systems (Mocerino, 2018). By harnessing AI technologies, construction firms can achieve greater precision, accuracy, and efficiency in project execution, thereby improving project outcomes and enhancing overall competitiveness in the market. Moreover, the integration of AI fosters a culture of continuous improvement and innovation within the industry, driving progress towards a more sustainable, resilient, and technologically advanced built environment (Chen et al., 2022).

These standard technologies allow construction companies to have increased accuracy in data analysis and formulate better strategies that benefit all stakeholders involved (Lee et al., 2018). In addition, as projects are temporary and multi-organisational and rely on planning and scheduling models, the construction industry would benefit more than other industries to incorporate technologies (Akinosho et al., 2020).

Table 2
Real-time uses of artificial intelligence in construction.

AI in Construction	Description
Predictive Maintenance	AI algorithms can analyse real-time data from sensors embedded in machinery and equipment on construction sites (You et al., 2020). By monitoring variables such as temperature, vibration, and usage patterns, AI can predict potential equipment failures before they occur. This enables proactive maintenance, minimising downtime and reducing costly repairs (Yaseen et al., 2020).
Safety Monitoring	AI-powered cameras and sensors can continuously monitor construction sites in real-time to detect safety hazards such as falls, unauthorised personnel, or equipment malfunctions. These systems can issue alerts to supervisors or automatically shut down operations in hazardous situations, thus improving overall safety on the site (Winge et al., 2019).
Resource Optimisation	AI algorithms can optimise the use of resources such as materials, labour, and equipment based on real-time data inputs. AI can adjust construction schedules and resource allocations in response to changing weather conditions, material availability, or workforce productivity, thereby maximising efficiency and reducing waste (Ginzburg et al., 2018).
Quality Control	AI-driven computer vision systems can inspect construction materials and components in real-time to ensure compliance with quality standards and specifications. These systems can detect defects, deviations, or anomalies during the construction process, allowing for immediate corrective actions to be taken to maintain quality standards (Fang et al., 2021).

Table 3
Technical uses of artificial intelligence in construction.

AI in Construction	Description
Data Integration:	AI applications in construction rely on integrating data from various sources such as sensors, drones, BIM models, and historical project data. Ensuring seamless data integration requires robust data management systems and interoperability standards to enable AI algorithms to access and analyse diverse data sources effectively (Rakesh et al., 2023).
Machine Learning Models	AI algorithms used in construction often employ machine learning techniques such as supervised learning, unsupervised learning, and reinforcement learning. These models require extensive training on labelled datasets to learn patterns, predict outcomes, and make decisions autonomously (Sacks et al., 2020). Ensuring the accuracy and reliability of machine learning models is crucial for their successful deployment in construction applications.
Edge Computing	Real-time AI applications in construction often require processing large volumes of data generated by sensors and cameras at the edge of the network, near the construction site. Edge computing technologies enable AI algorithms to run locally on edge devices, reducing latency and bandwidth requirements while ensuring timely decision-making and response in dynamic construction environments (Saeed et al., 2022).
Human-AI Collaboration	Effective deployment of AI in construction requires collaboration between AI systems and human workers. Human-AI collaboration involves integrating AI tools into existing workflows, providing training and support for workers to interact with AI systems, and leveraging human expertise to interpret AI-generated insights and make informed decisions on construction projects (Sachs et al., 2019).

Following this introduction and background, the paper is organised into several sections to provide a structured analysis of the research findings. In Section 3, the research methodology employed in this study is outlined, detailing the systematic approach adopted to conduct the literature review and map AI applications in the construction industry. Section 4 presents the results and general observations regarding the relevant SDGs in construction, clarifying how AI can contribute to achieving these goals effectively. This section provides a comprehensive overview of the direct and indirect impact of AI on a construction project. In Section 5, a detailed discussion of the results is offered, providing deeper insights and interpretations into the implications of AI integration for sustainability in the construction sector. Finally, Section 6 concludes the paper by summarising the key findings, discussing their implications for future research and practice, and suggesting potential avenues for further exploration.

3. Methodology

This study aims to outline key AI technologies aiding the construction industry in achieving the UN's SDGs. Integrating AI can enhance construction efficiency, sustainability, and alignment with SDG principles. A systematic literature review was conducted which adheres to the PRISMA protocol and ensures research replicability (see http://prisma-statement.org). The chosen methodology was based on the structured and unbiased synthesis that systematic reviews offer. By providing comprehensive overviews of existing research on specific topics, they inform decision-making and guide future actions across various fields as seen in Table 4.

AI-related literature is exclusively sourced from reputable academic journals, covering established and emerging technologies. By examining current applications, maturity levels, and their potential to address

Table 4
Statistical information of the data.

Domain	Specifics
Data Source	Scopus bibliographic repository
Covered Period	From 1 January 2000 to 15 November 2023
Number of Publications	91
Covered country contexts	64
Number of authors	314
Number of universities	53
Number of publishing sources	39
Number of papers in each SDG	SDG 6: 5 SDG 7: 12 SDG 8: 16 SDG 9: 22 SDG 11: 13 SDG 12: 7 SDG 13 12 SDG 15: 5 SDG 17: Interconnected within all the papers
Number of papers in each project state	Design: 14 Planning: 19 Construction:36 Operation and maintenance: 22

sustainability challenges, this study provides insights crucial for advancing sustainable practices in construction.

Stage 1 (planning stage) focused on the included research objectives that answer the research questions, keywords, and a set of exclusion and inclusion criteria. The primary aim of this study is to identify and highlight the predominant AI technologies that are making significant contributions towards achieving the UN's sustainability goals. While some research papers examine effective construction methods that contribute to sustainability objectives, there needs to be more research analysing the prevalent AI technologies employed across the four primary phases of Construction. Based on the literature analysis conducted, it was found that nine SDGs emerged as frequently mentioned and emphasised across various studies and sources as seen in Table 5. These SDGs represent key areas of focus and priority for policymakers, organisations, and stakeholders involved in sustainable development efforts.

The following 26 keywords were used to form a defined a search criteria: "Artificial Intelligence" AND "Sustainability" AND "Construction Industry" OR "Buildings" OR "Construction Projects" OR "UN Sustainable Development Goals" OR "Development Goals" OR "Automation" OR "Robotics" OR "Urban Development" OR "AI Application" OR "Sustainable Building Design" OR "Sustainable Urban Planning" OR "Sustainable Architecture" OR "Renewable Energy" OR "Energy Efficiency" OR "Green Building" OR "Sustainable Materials" OR "Waste Reduction" OR "Climate Change" OR "Emissions" OR "Lifecycle" OR "Civil Construction".

Based on the findings from the literature review, keywords co-occurrences for AI in Construction concerning sustainability development goals were established. The results showed that 38 broad technology themes are co-occurrent with sustainability goals. Additional keywords were analysed but did not establish or identify other technology areas. Seven of the thirty-eight key AI themes were frequently mentioned in the journal articles, namely, Decision support systems ($n = 230$), Machine learning ($n = 159$), Internet of things ($n = 128$), Automation ($n = 109$), Big data ($n = 76$), Deep Learning ($n = 76$) and Robotics ($n = 55$). The clustering of central keywords not only outlined the research landscape's boundaries but also a comprehensive overview of AI technologies that showcase a notable alignment with the sustainability goals of the United Nations.

The keyword search was conducted in July 2023 and obtained 1490 results that met the stipulated search parameters (from January 2000 to July 2023). Following the removal of duplicated journal articles, the retained count settled at 1358 papers, encompassing research contributions that extend beyond the confines of the university library database. The search mechanism encompassed over 400 bibliographic repositories, notably bibliographic repositories such as Scopus, ScienceDirect, Web of Science, the Directory of Open Access Journals and Wiley Online Library. As demonstrated in Table 6, a set of criteria was systematically formulated to curtail the volume and intricacy of the forthcoming review process, thereby facilitating efficient article

Table 5
Construction-related sustainable development goals (Berawi et al., 2023).

Goals	Objectives
SDG 6: Water	- Ensure access to clean and safe water. - Improve water quality through effective treatment and pollution reduction. - Enhance water use efficiency and sustainable management of water resources.
SDG 7: Clean Energy	- Increase the share of renewable energy sources in the global energy mix. - Promote energy efficiency measures across various sectors. - Ensure universal access to affordable, reliable, and modern energy services.
SDG 8: Decent Work and Economic Growth	- Promote sustained, inclusive, and sustainable economic growth. - Focus on youth employment - Protect labour rights
SDG 9: Innovation and Infrastructure	- Develop and upgrade reliable and sustainable infrastructure. - Foster innovation and encourage the growth of sustainable industries. - Enhance research and development activities to support technological advancements.
SDG 11: Sustainable Cities	- Promote inclusive and sustainable urbanisation. - Provide adequate and affordable housing. - Ensure efficient and sustainable transportation systems within cities.
SDG 12: Consumption and Production	- Reduce waste generation and promote recycling and reuse. - Encourage sustainable practices in industries, businesses, and households. - Support the transition to circular economies.
SDG 13: Climate Action	- Strengthen resilience and adaptive capacity to climate-related impacts. - Integrate climate change measures into national policies, strategies, and planning. - Raise awareness and enhance capacity for climate change mitigation, adaptation, impact reduction, and early warning.
SDG 15: Life of Land (Biodiversity)	- Protect, restore, and sustainably manage ecosystems. - Combat land degradation and deforestation. - Promote the conservation of plant and animal species.
SDG 17: Partnership for the Goals	- Collaboration and partnerships amongst stakeholders - Increase financial resources to support the implementation of sustainable development initiatives - Importance of data collection, monitoring, and reporting mechanisms

Table 6
Exclusion and inclusion criteria derived from Yigitcanlar et al. (2020).

Primary Data		Secondary Data	
Inclusionary	Exclusionary	Inclusionary	Exclusionary
Journal articles Peer-reviewed Full-text available online Published in English Government reports Conferences	Duplicate records Books and chapter Industry reports	AI in construction Opportunities and Challenges in construction Relevant to the research objective	Not AI in construction-related Irrelevant research objectives

screening. In this context, primary data encompasses research outputs meticulously generated by individuals, serving as purposeful tools for comprehending and resolving intricate research questions. Conversely, secondary data assumes the form of research contributions from governmental bodies and construction institutions, collectively contributing to the knowledge landscape.

In stage 2 (review stage), the remaining 1263 articles were assessed against category formulation, as seen in Table 7. As a result of this evaluation, the articles were further refined, which resulted in 578 remaining articles. The title, abstract and keywords of the remaining 578 articles were screened according to the exclusion criteria and the number of relevant articles was eventually reduced to 91.

In Stage 3 (reporting), the screening processes aimed to analyse the selected articles according to pre-defined categories to assess similarities and differences (Yigitcanlar et al., 2021a). The four-step method was then used to classify the reviewed literature into specific themes (Butler et al., 2020; Yigitcanlar et al., 2021b). The first step highlighted significant technologies that play a part in reducing carbon emissions and helping meet sustainability goals. Secondly, the most important ranked themes were categorised and reviewed as aligned with the research aims. The third step was cross-checking the categories with other review studies and identifying any additional relevant SDG in construction. Lastly, the themes were categorised and finalised in the planning, design, construction operation and maintenance under common themes. Fig. 4 displays the overview of the process of selecting papers.

Subsequently, the selected papers were examined and categorised based on the specific sustainability development goals (SDGs) they addressed and AI sub-categories that were frequently mentioned in the articles. Additionally, the papers were later organised based on the direct and indirect relationships between SDG targets and the construction industry, as seen in Fig. 5. They were then assessed to determine which specific AI subcategory would exert the most significant influence on each respective target. Other relevant peer-reviewed studies further evaluated these overarching themes.

Additionally, the chosen articles were segmented into four distinct phases: the 'planning phase' ($n = 21$), the 'design phase' ($n = 25$), the actual 'construction phase' ($n = 27$), and the subsequent phases of 'operation and maintenance' ($n = 18$). Each phase involves common and distinct AI technologies, which vary in impact on the associated SDG.

Table 7
Category formulation criteria derived from Butler et al. (2021) and Yigitcanlar et al. (2020).

Selection Criteria	
Authors	- Using qualitative data, identify the key authors relevant to AI in the construction industry - Group AI technologies relating to a particular phase, sustainability goal and form categories - Check the consistency and AI categories against other literature - Shortlist categories and analyse recent literature reviews - The final categories are verified, classified, and finalised - Relevant categories are distributed and selected the most pertinent categories
Literature	- Relevant to sustainable construction - Quality from scholarly publications - Comprehensive coverage of AI role in construction - Priories literature with real-world case studies - Include literature that explore AI technologies and methodologies specifically addressing sustainability challenges and opportunity - Scalability of AI solutions - Consider literature that emphasises the involvement of industry stakeholders, policymakers, and community members - Discus emerging trends in the field of AI in construction to enhance sustainability

4. Results

4.1. General observations

The number of publications published in recent years has shown the increased interest in AI helping the built environment become more environmentally sustainable. This is evident as 78% of the 91 articles were published in the last three years (5 in 2020, 9 in 2021, 25 in 2022 and 22 in 2023). Many of the authors were affiliated with academic institutions in China ($n = 12$), Australia ($n = 9$) and the United States ($n = 8$). This global distribution signifies collaborative efforts in utilising AI to address ecological challenges in the industry. China's significant representation underscores its commitment to innovative solutions, while Australia and the United States demonstrate their dedication to sustainable construction practices. This collective international engagement highlights AI's potential for fostering sustainability in construction on a worldwide scale. As shown in Fig. 6, the growth of AI literature concerning environmentally sustainable practices has drastically increased in recent years.

The articles were categorised and analysed based on how often different AI sub-categories were mentioned, as detailed in Table 8. These findings consistently highlight the importance of AI-related tasks across various project phases. The prevalence of AI tasks across these phases emphasises its significance, showcasing its broad applicability and central role in addressing diverse project needs. ML appears regularly as a contributor, with varying levels of involvement, indicating its supportive role in phases where data-driven approaches are crucial. While DL's consistently lower presence suggests a more specialised application within the project, emphasising its relevance in specific areas where its unique capabilities are essential.

In the context of leveraging AI to enhance sustainability within construction projects, an analysis of 91 articles revealed a distinct pattern: only two authors emerged as contributors to more than one paper: Frahzadil ($n = 2$) and Kiomarsi ($n = 2$). An assessment of the author's h-index scores highlighted three prominent researchers: Kovac ($n = 38$), Banins ($n = 33$) and Clements-Croom ($n = 28$). These scores recognise the influence of these authors in utilising AI to advance sustainability within construction contexts. Interestingly, no single author held a dominant position in the literature. The contributions were widespread across various authors, outlined the diverse and collaborative nature of the literature, and depicted a range of viewpoints and cumulative knowledge.

Given the specific focus on AI and sustainability in the literature review, it is unsurprising that a significant portion of the articles ($n = 10$) were published in the Sustainability journal. These papers addressed the entire lifecycle of construction. The remaining papers were published in 38 journals, focusing on sustainability and how construction projects can utilise AI technologies to reduce carbon emissions, efficient energy consumption, and project waste. Table 9 presents the relevant SDG and which construction phases were frequently mentioned within the papers.

It is essential to highlight that several SDGs are not inherently aligned with the core functions of the construction industry, as seen in Table 10. While the construction sector plays a crucial role in shaping our built environment, fostering economic growth, and enhancing infrastructure, it does not directly address or encompass the entire spectrum of SDGs, as seen in Table 2. These goals, each addressing distinct global challenges, require specialised approaches and interventions outside the immediate purview of construction.

For instance, SDG 1 focuses on addressing poverty, which requires a broader set of economic and social policies that extend beyond the construction industry's primary functions. Similarly, SDG 2, which seeks to achieve zero hunger, is primarily concerned with food security, an area unrelated to the construction's primary function of building physical infrastructure. Further, although the construction sector can impact worker health and safety, it needs to encompass the comprehensive

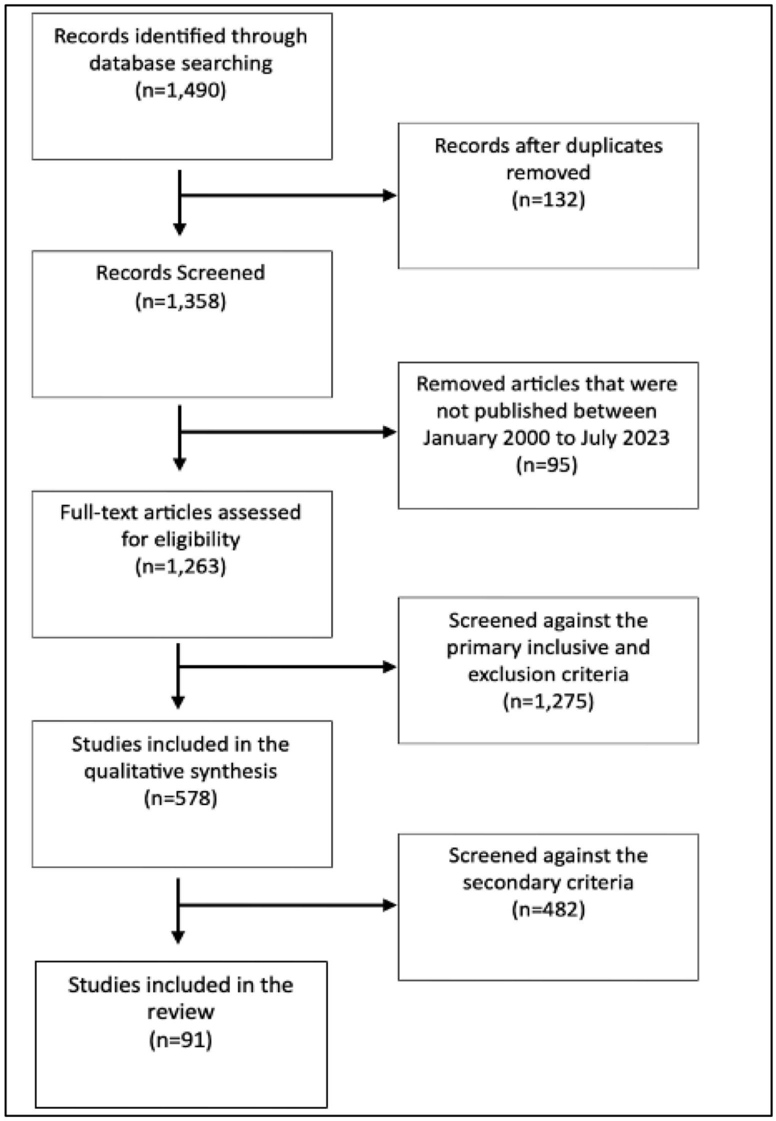

Fig. 4. The PRISMA selection process of relevant literature.

healthcare and well-being objectives of SDG 3.

While construction projects can contribute to educational initiatives, such as constructing schools, the industry itself does not serve as the primary driver of the educational goals central to SDG 4. Gender equality, a pivotal issue in SDG 5, remains a critical social concern but isn't the principal focus of the construction sector, despite ongoing efforts to foster gender diversity and equality within it. Income inequality, a central theme of SDG 10, is indirectly influenced by the construction industry through job creation and wage structures, but addressing income inequality is not the core mission of the sector. SDG 14, addressing life below water, is unrelated to construction, an industry predominantly on land, with no direct impact on marine ecosystems. Lastly, establishing peace, justice, and strong institutions, as mentioned in SDG 16, does not fall within the immediate purview of the construction industry, as this goal primarily involves governance, law enforcement, and related matters.

4.2. Sustainable development goals and artificial intelligence in construction

The pivotal role of the construction sector in driving societal development and infrastructure creation underscores the urgent imperative to achieve nine directly related sustainable SDGs goals. Embracing AI within the construction industry has emerged as a critical strategy for projects to elevate sustainability efforts while pursuing SDGs. The seamless fusion of SDGs and AI technologies within construction underscores their transformative potential, catalysing a significant reshaping of the construction landscape.

However, the literature review highlights the imperative for the construction industry to expedite the integration of AI and SDGs, attributed to the growing complexity of construction projects and a tendency to prioritise economic gains over environmental and social considerations (Egwim et al., 2021). As such, there is a pressing need for concerted efforts from all relevant stakeholders to actively contribute to attaining these crucial goals. Collaboration amongst industry stakeholders is essential to promote sustainable practices that align with the SDGs (Pan et al., 2023). Governments can implement supportive policies, local communities can ensure projects meet their needs and adhere to sustainability principles, construction companies can invest in green solutions, and architects and engineers can incorporate sustainable designs (Grabowska et al., 2022). This collective effort advances the SDGs and establishes new industry standards, becoming a global model for sustainable construction practices.

4.2.1. SDG 6: clean water and sanitation

Providing clean water and sanitation is considered in SDG 6, which

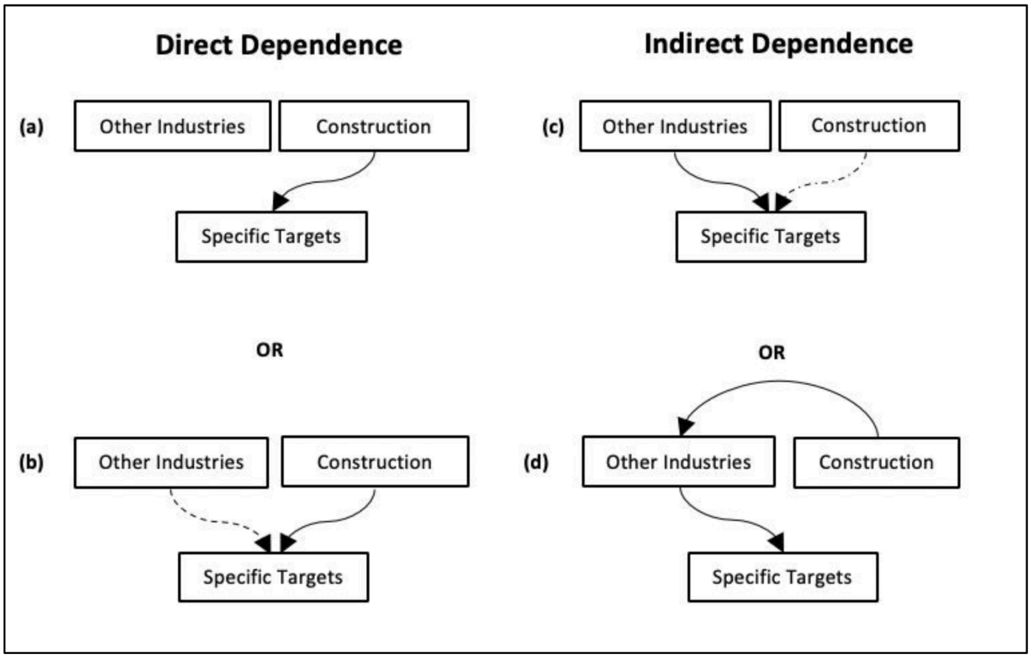

Fig. 5. Process for defining direct and indirect dependencies of SDG targets in the construction industry.

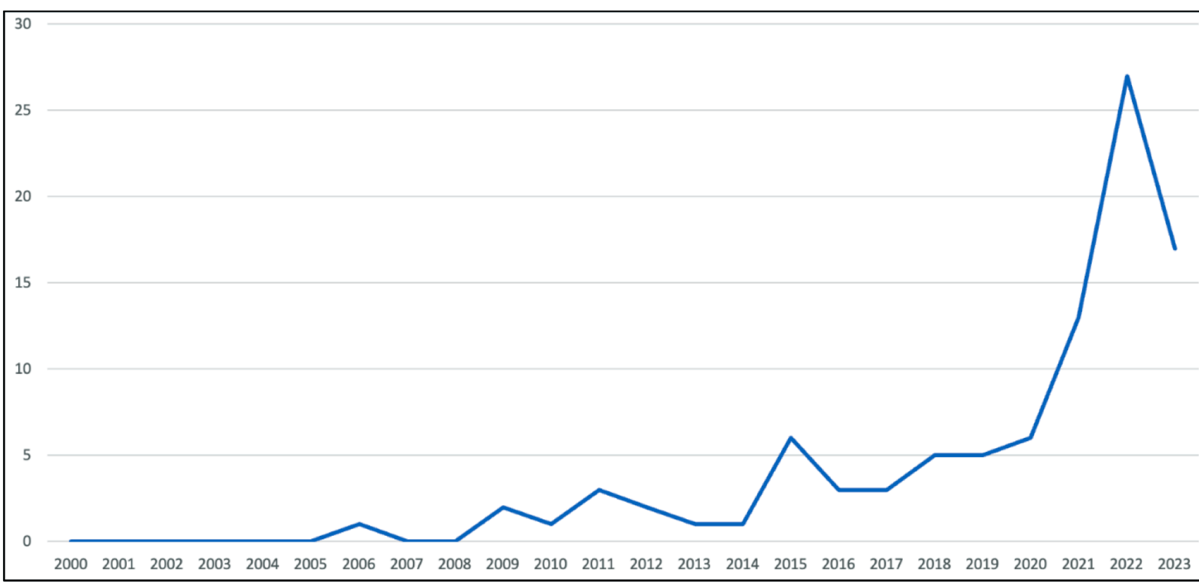

Fig. 6. Distributions of publication by year.

Table 8
Sub-categories of AI mentioned in the analysed articles.

Phases	Artificial intelligence	Machine learning	Deep learning	Total
Planning	8	9	4	21
Design	15	7	3	25
Construction	14	9	4	27
Operation and maintenance (O&M)	15	1	2	18
Total	52	26	13	

consists of 8 targets and 11 indicators. The main objectives centre around water and sanitation availability and sustainability management that promotes responsible construction practices. Construction projects demand substantial water for concrete mixing, dust control, and site preparation. Construction organisations must protect freshwater bodies near construction sites from contamination (Opoku, 2022). The design of intelligent, innovative, and sustainable buildings offers improvement in water use and could contribute to minimising its impact on the natural environment. The construction industry can leverage the following, as shown in Table 11, vital technologies to attain this objective.

4.2.2. SDG 7: clean energy

SDG 7′s emphasis on clean and sustainable energy aligns closely with the objectives of AI in construction through 5 targets and 6 indicators. Construction significantly contributes to greenhouse gas emissions, primarily through the energy used in building operations and construction processes. It ensures access to affordable, reliable, sustainable, and modern community energy (Fei et al., 2021). This goal recognises the pivotal role of energy in construction projects and highlights the

Table 9
Sustainable development goals relevant to the construction industry.

Phases	SDG 6	SDG 7	SDG 8	SDG 9	SDG 11	SDG 12	SDG 13	SDG 15
Planning	11	5	3	6	3	5	4	9
Design	1	24	9	11	4	6	8	0
Construction	4	10	4	23	6	24	15	4
O&M	4	17	11	4	14	3	11	1
Total	20	56	27	44	27	38	38	14

Table 10
Sustainable development goals not relevant to the construction industry.

Phases	SDG 1	SDG 2	SDG 3	SDG 4	SDG 5	SDG 10	SDG 14	SDG 16
Planning	0	0	0	0	0	0	0	0
Design	0	0	1	0	0	0	0	0
Construction	0	0	0	0	0	0	0	0
O&M	0	0	1	0	0	0	0	0
Total	0	0	2	0	0	0	0	0

Table 11
Potential of AI for SDG6.

Construction activity	Stage	Sustainability pillar	Potential of AI
Water Distributions	Design and Planning	Environmental	Predicting and preventing pipeline failures, optimising water flow, and ensuring a consistent and reliable water supply (Naser, 2019).
Monitoring Water	Planning and Construction	Environmental	Leverage satellite data to monitor water resources, identify water scarcity areas, and plan projects accordingly (Arsiwala et al., 2023).
Simulating Water Patterns	Construction	Environmental	Simulating and analysing the patterns of water infrastructure to model the impact of various scenarios and optimise water usage (Aparicio et al., 2020).
Smart Water Infrastructure	Construction	Environmental	Deploying sensors and Internet of Things (IoT) devices throughout water infrastructure to monitor water quality, detect leaks, and manage water distribution (Rodriguez-Gracia et al., 2023).
Water Quality Monitoring	Construction	Environmental	ML algorithms analyse real-time water quality data by identifying contaminants, assessing the impact of construction activities on water quality, and ensuring compliance with environmental standards (Arsiwala et al., 2023).

need for responsible and sustainable energy practices. This alignment benefits the construction sector and contributes to global efforts to combat climate change and ensure access to clean energy (Hartenburger et al., 2018). The construction industry can leverage the following, as shown in Table 12, key technologies to attain this objective.

4.2.3. SDG 8: decent work and economic growth

SDG 8 promotes sustained, inclusive, and sustainable economic and work growth through 12 targets and 16 indicators. It emphasises the interconnectedness of sustainable policies, striving for inclusive prosperity and decent work opportunities (Aparicio et al., 2020). The construction industry enhances safety standards by identifying and mitigating potential hazards in real-time, aligning with a focus on decent work opportunities and workforce well-being. This diversification fosters innovation and bridges traditional practices with technology, ensuring the construction sector remains adaptable and competitive. Furthermore, these efficiencies benefit the construction sector by increasing profitability and competitiveness, creating jobs, and improving infrastructure (Bhattacharya and Chatterjee, 2022). The construction industry can leverage the following, as shown in Table 13, key technologies to attain this objective.

4.2.4. SDG 9: innovation and infrastructure

SDG 9 seeks to foster innovation, build resilient infrastructure, and promote sustainable industrialisation through 8 targets and 12 indicators. The construction industry can contribute to the goal by prioritising resilient infrastructure and circular economy practices, adopting innovative technologies, and fostering public-private partnerships. The construction industry should develop and align its strategies with the SDG at the organisation and the project level. It plays a crucial role in reducing the environmental footprint of buildings, aligning with sustainable urban development goals (Mocerino, 2018). This ensures that projects delivered (new build or refurbishment) demonstrate sustainable development. The construction industry can leverage the following, as shown in Table 14, vital technologies to attain this objective.

4.2.5. SDG 11: sustainable cities

SDG 11 seeks to make cities inclusive, safe, resilient, and sustainable through 10 targets and 14 indicators. Cities use AI to create infrastructure that supports sustainable urban development and long-term liveability. It does so by building essential infrastructure, affordable housing, and sustainable urban spaces and promoting resource efficiency aligned with community needs (Fei et al., 2021). The construction sector is central to optimising resource use, reducing waste, and ensuring efficient construction practices to create sustainable cities (Barros et al., 2021). It extends beyond infrastructure, emphasising inclusive and resilient communities. As urbanisation surges, construction's commitment to sustainability is crucial for shaping cities' futures (Yigitcanlar, Fabian, & Coiacetto, 2008). The construction industry can leverage the following, as shown in Table 15, vital technologies to attain this objective.

4.2.6. SDG 12: consumption and production

SDG 12 seeks to reduce resource consumption, minimise waste generation, and promote materials recycling through 11 targets and 13 indicators. The construction industry can further support the goal by promoting responsible consumption patterns, optimising building designs for durability and energy efficiency, and collaborating with stakeholders to develop sustainable standards and practices (You et al., 2020). This multifaceted approach contributes to safer and more resilient urban environments and ensures affordable housing is

Table 12
Potential of AI for SDG7.

Construction Activity	Stage	Sustainability Pillar	Potential of AI
Predictive Maintenance	Repair and Maintenance	Economic	Utilise AI algorithms for predictive maintenance of building systems (Rodriguez-Gracia et al., 2023).
Climate Control	Repair and Maintenance	Environmental and Economic	Optimise heating and cooling systems, considering occupancy patterns, weather forecasts, and building conditions to maximise energy efficiency (Rakesh et al., 2023).
Energy Performance	Repair and Maintenance	Environmental and Economic	Predict and analyse the energy performance of buildings that allow for iterative improvements (Huang, 2023).
Energy-Efficient Supply Chains	Construction	Environmental and Economic	AI optimises construction supply chains, reducing energy consumption in transportation and logistics (Naser, 2019).
Monitor Energy Consumption	Planning and Construction	Environmental and Economic	Install IoT sensors and smart meters to monitor real-time energy consumption within construction sites and buildings (Rakesh et al., 2023).
Schedule Optimisation	Planning and Construction	Environmental and Economic	AI algorithms that optimise schedule and resource allocation in which reduce energy-intensive process and enhance overall efficiency (Tatiya et al., 2018)
Building Layout	Design	Environmental and Social	Optimise building layouts, materials, and configurations for enhanced energy efficiency (Liu et al., 2015).
Intelligent Lighting Systems	Design	Environmental and Social	Implement AI-driven lighting systems that respond to occupancy patterns, adjusting lighting levels based on real-time usage data to minimise energy waste (Oyedele et al., 2021).

cost-effective, efficient, and inclusive. Through these efforts, the construction sector can foster responsible production and consumption practices for a more sustainable future (Akinosho et al., 2020). The construction industry can leverage the following, as shown in Table 16, vital technologies to attain this objective.

4.2.7. SDG 13: climate action

SDG 13 is a critical goal as it undermines the remaining 16 SDGs and seeks to mitigate greenhouse gas emissions, promote energy efficiency, enhance resilience to climate change, and foster responsible and sustainable construction practices (Opoku, 2015). It ensures responsible construction practices that comply with environmental regulations and supports substantial reductions in the carbon footprint of construction projects, fostering sustainability in the industry. By implementing the five goals and eight indicators, the construction industry's role extends to developing carbon capture and storage technologies, driving innovation, and researching emissions reduction and climate resilience. These efforts position the construction sector as vital in global initiatives to combat climate change and achieve a more sustainable future. The construction industry can leverage the following, as shown in Table 17, critical technologies to attain this objective.

Table 13
Potential of AI for SDG8.

Construction activity	Stage	Sustainability pillar	Potential of AI
Job Creation and Retention	Construction	Economic	Diversify the industry through tech-related roles, including AI developers, data scientists, robotics technicians, cybersecurity experts, and AR/VR developers (Wahbeh et al., 2020).
Productivity	Construction	Economic	Increase productivity through automation, predictive analytics, and streamlining scheduling and resource allocation (Hsu, Chang, Chen & Wu, 2020).
Transparent Transactions	Planning	Economic	Implement blockchain technology for transparent and secure financial transactions, ensuring accountability and reducing fraud in construction projects (Singh et al., 2023a)
Dynamic Pricing Models	Planning and Construction	Economic	Accurate and real-time cost estimation, helping construction companies remain competitive and financially sustainable (Tatiya et al., 2018).
Repetitive Tasks	Planning and Construction	Economic	Handle repetitive tasks, increasing productivity and allowing human workers to focus on more complex and value-added activities (Pradhananga et al., 2021).
Decision Making	Construction	Economic and Social	Allowing stakeholders to make informed decisions, identify trends, and optimise operations (Lin et al., 2021).
Stakeholder Collaboration	Design and Planning	Economic and Social	Enable key stakeholders work together more efficiently through generate design collaboration (Alsakka et al., 2023).
Site Safety	Construction	Social	Monitor construction sites for safety compliances, identify potential hazards, and ensure safety protocol adherence (Teferi et al., 2018).
Human Resource Management	Planning	Social	Streamline the hiring processes, talent acquisition, and workforce planning for improved organisational efficiency (Dickens et al., 2020).
Skilled Workforce Development	Planning	Social	Provide personalised and adaptive learning experiences to enhance skills and productivity (Xiang et al., 2022).

Table 14
Potential of AI for SDG9.

Sustainable construction	Stage	Sustainability pillar	Potential of AI
Autonomous Construction Vehicles	Construction	Economic	AI enable autonomous operations, improving precision, safety, and efficiency in tasks such as excavation and transportation (Alsakka et al., 2023).
Manual Labour	Construction	Economic	Robotic systems with AI capabilities for tasks like bricklaying, welding, and other repetitive activities, increase construction speed and accuracy (Barbosa Júnior et al., 2023).
Construction Plans	Design and Planning	Economic	Utilise AR for visualising construction plans, providing on-site guidance, and enhancing collaboration amongst construction teams for improved precision (Bigham et al., 2019).
Infrastructure Development	Design and Planning	Economic	AI optimises plans and designs, reduces costs, improves quality and durability, enables predictive maintenance, mitigates environmental impact, and enhances disaster resilience (Columbus, 2017).
Project Planning	Planning and Construction	Economic	Streamlines project planning, risk mitigation, quality control and safety enhancement (Oyedele et al., 2021).
Resource Allocation	Planning	Economic and Social	AI offers predictive insights and enhanced decision-making by optimising resource allocation and ensuring the right resources are allocated at the right time (Adams, 2017).
3D Printing	Construction	Environmental and Social	Optimise the printing process, reducing material waste and enhancing the efficiency of constructing complex structures (Yaseen et al., 2020)
Smart Construction Equipment	Construction	Social	Real-time monitoring, predictive maintenance, and efficient operation reduce downtime and enhance productivity (Singh et al., 2023b).

4.2.8. SDG 15: life of land (Biodiversity)

SDG 15 seeks to protect, restore, and promote conservation through ecosystem preservation, reforestation and land restoration, habitat conservation, ecological corridor creation, minimising land footprint, biodiversity-friendly landscaping, and sustainable land use planning (Kumar et al., 2019). By achieving the 12 targets and 14 indicators, these actions collectively bolster the preservation and improvement of ecosystems and ensure long-term sustainability. Furthermore, it facilitates informed stakeholder engagement in land use decisions, helping to balance development and environmental conservation for long-term sustainability (Boje et al., 2020). The construction industry can leverage the following, as shown in Table 18, vital technologies to attain this objective.

Table 15
Potential of AI for SDG11.

Sustainable construction	Stage	Sustainability pillar	Potential of AI
Efficient Resource Management	Planning	Environmental	AI-driven tools optimise resource management using materials, energy, and water efficiently (Yigitcanlar et al., 2023)
Building Design	Repair and Maintenance	Environmental	Utilise AI to optimise the energy consumption of buildings, adjusting heating, cooling, and lighting systems based on occupancy patterns and environmental conditions (Gao et al., 2020).
Smart Urban Planning	Repair and Maintenance	Environmental	Utilise AI-driven generative design algorithms to optimise urban planning, considering factors such as traffic flow, green spaces, and energy efficiency in constructing buildings and infrastructure (Goubran, 2019).
Waste Reduction	Repair and Maintenance	Environmental	AI tools enable automated sorting, streamlining processes, and conserving resources (Ajayi et al., 2020).
Smart Cities	Planning and Construction	Environmental and Social	AI optimises transportation, enhances public services, manages energy and waste and improves security (Amleida et al., 2022).
Urban Green Spaces Planning	Repair and Maintenance	Environmental and Social	Utilise AI in the planning of urban green spaces, optimising their layout for environmental benefits, aesthetics, and public well-being (Xiang et al., 2022).
Community Engagement	Repair and Maintenance	Social	AI provides accessible participation platforms and data-driven insights by fostering collaboration, informing policies, and enhancing transparency (Yaseen et al., 2020).

4.2.9. SDG 17: partnerships for the goals

SDG 17 is an important goal as it outlines the global partnerships for sustainable development through 19 targets and 24 indicators. In addition, recognising the interconnectedness of nations, industries and communities in achieving shared goals. The construction industry can strategically collaborate with public and private organisation to address complex challenges, from infrastructure development to environmental conservation (Çetin et al., 2021). It extends beyond collaboration as it promoted the commitment to fosterer inclusive, participatory decision-making processes that empower all stakeholders to contribute to the SDG agenda (Çetin et al., 2021). The construction industry can utilise the essential technologies outlined in Table 19 to achieve these objectives.

Table 16
Potential of AI for SDG12.

Sustainable construction	Stage	Sustainability pillar	Potential of AI
Resource Planning	Construction	Economic	AI can analyse historical data and predict resource requirements for construction projects, allowing for better resource planning and reducing waste (Dickens et al., 2020).
Sustainable Materials	Construction	Economic and Environmental	AI can help identify sustainable sources for construction materials and track their journey through the supply chain Berawi (2023).
Construction Equipment	Construction	Environmental	Integrating AI into construction equipment optimises energy usage and reduces emissions (Qiu et al., 2021).
Transportation and Mobility	Design and Planning	Environmental	AI-driven transportation systems reduce congestion, improve public transportation, lower emissions through electric and autonomous vehicles, and enhance safety (Roslo, 2022).
Environmental Impact Assessment	Planning	Environmental	Predict and assess construction projects environmental impact, considering emissions, habitat disruption, and resource depletion (Onyelowe et al., 2022).
Waste Management	Planning	Environmental	Utilise AI in waste sorting processes to enhance efficiency and accuracy, ensuring that materials are appropriately categorised for recycling (Almeida et al., 2022).
Life Cycle Assessment	Repair and Maintenance	Environmental	Integrate AI into life cycle assessments, considering environmental impacts throughout their life cycle and making informed decisions to minimise resource consumption (Fnais et al., 2022).

Table 17
Potential of AI for SDG13.

Sustainable construction	Stage	Sustainability pillar	Potential of AI
Carbon Footprint Monitoring	Construction	Environmental	Monitor and analyse the carbon footprint of construction projects by tracking emissions from construction activities, transportation, and material production (Kanyilmaz et al., 2022).
BIM and Energy Simulation	Design	Environmental	Simulate and analyse the energy performance of buildings and reducing carbon emissions (Pan et al., 2023).
Climate Modelling	Design and Planning	Environmental	AI can predict and model future climate trends, allowing for informed decisions about project design, location, and materials to ensure long-term resilience to changing climate conditions (Naser, 2019).
Environmental Monitoring	Design and Planning	Environmental	AI provides real-time data analysis, resource efficiency optimisation and emission monitoring (Wahbeh et al., 2020).
Green Building Certification	Planning	Environmental	AI-driven data analysis can support resilience planning by ensuring regulatory compliance and optimising site selection (Mahbub, 2008).
Resilience to Climate Change	Planning	Environmental	AI can analyse climate data, create predictive models, guides material selection, enables adaptive design, and assesses climate risks (Xiao et al., 2018).
Material Selection	Planning and Construction	Environmental	Identify and optimise the use of energy-efficient and sustainable construction materials, considering factors such as embodied carbon and life cycle assessments (You et al., 2020).
Mitigating Greenhouse Gas Emissions	Planning and Design	Environmental	AI optimises energy use, promotes sustainable materials analyses and reduces waste (Zhang, 2021).
Renewable Energy Integration	Planning and Design	Environmental	Optimise the deployment of renewable energy sources and ensuring efficient energy production (Gao et al., 2020).

4.3. Sustainable development goals and artificial intelligence in construction phases

4.3.1. Planning phase

The planning phase of a construction project holds significant importance, serving as the cornerstone upon which the success of the entire project is built. It is during this phase that vital decisions are made regarding timelines, budgets, and quality standards, which ultimately shape the project's outcome (Huang, 2023). A meticulously developed plan sets the stage for seamless implementation, guaranteeing efficient allocation of resources and achievement of project objectives within defined parameters. By emphasising precision and comprehensiveness in the planning process, construction teams can enhance project success while reducing risks and resource inefficiencies (You et al., 2020).

The literature review found 20 papers that highlighted the importance of AI and SDG in the planning phase. ML was highlighted in 8 instances, showcasing its utility in analysing extensive datasets and deriving actionable insights to inform decision-making processes during project planning (Srivastava et al., 2022). Similarly, AI was also prominently featured in 8 papers, indicating its widespread recognition as a transformative tool for optimising various aspects of construction project planning, such as resource allocation, risk management, and scheduling. Lastly, DL emerged as a focal point in 3 papers, albeit to a lesser extent compared to ML and AI. Nonetheless, its inclusion underscores the growing interest in leveraging advanced machine learning techniques to address complex challenges encountered during the

Table 18
Potential of AI for SDG15.

Sustainable construction	Stage	Sustainability pillar	Potential of AI
Sustainable Land Use	Construction	Economic and Environmental	AI assesses and optimises land use patterns by identifying suitable areas for development (Lepczyk et al., 2017)
Invasive Species Management	Construction	Environmental	Employ AI to identify and manage invasive species that may be introduced during construction (Nagendra et al., 2018).
Soil Health Monitoring	Construction and Repair and Maintenance	Environmental	Monitor soil health before, during, and after construction by assessing soil composition, nutrient levels, and erosion risks to ensure sustainable land use (Tam et al., 2021).
Habitat Planning	Design	Environmental	Utilise AI to design and plan wildlife corridors that connect fragmented habitats by facilitating the movement of species and promoting genetic diversity (Srivastava et al., 2022).
Ecological Site Assessment	Planning	Environmental	AI can analyse environmental data to identify biodiversity hotspots, critical habitats, and areas with ecological sensitivity ecosystems (Statsenko et al., 2022).
Environmental Impact Assessment:	Planning	Environmental	AI improves Environmental Impact Assessments (EIAs) by analysing biodiversity, soil quality, and environmental data (Mahbub, 2008).
Construction Impact Prediction	Planning and Construction	Environmental	Predict and assess the environmental impact of construction by analysing potential disruptions to flora, fauna, and soil structure (Boje et al., 2020).
Erosion Control	Planning and Construction	Environmental	AI provides real-time monitoring, risk assessment, and automated alerts and suggesting soil stabilisation techniques (Ma et al., 2019).
Natural Resource Monitoring	Planning and Construction	Environmental	Implement AI to continuously monitor natural resources to ensure sustainable and responsible resource management during construction projects (Elmousalami, 2020).
Vegetation Management and Restoration	Repair and Maintenance	Environmental	Optimise planting patterns, species selection, and maintenance strategies for sustainable ecosystem restoration (Singh et al., 2023b).

Table 19
Potential of AI for SDG17.

Sustainable construction	Stage	Sustainability pillar	Potential for AI
Public-Private Partnerships (PPPs)	Repair and Maintenance	Economic	AI can facilitate cooperation between governments, businesses, and civil society organisations (Sacks et al., 2020).
Monitoring	Repair and Maintenance	Economic	Providing stakeholders with real-time data and insights to inform decision-making and promote accountability (Schönbeck et al., 2020).
Open Data Initiatives	Construction and Repair and Maintenance	Economic and Environmental	AI can analyse and visualise data on project performance, resource utilisation, and environmental impacts (Panteleeva et al., 2021).
Supply chain optimisation	Repair and Maintenance	Economic and Social	Optimise the integration of suppliers, contractors, and subcontractors across different regions (Poprach et al., 2019).
Sharing platforms	Repair and Maintenance	Social	AI-powered platforms can facilitate the sharing of best practices, lessons learned, and innovative solutions amongst construction stakeholders (Kulejewski et al., 2023).
Community Engagement Platforms	Repair and Maintenance	Social	AI-powered platforms can facilitate community engagement and participation in construction projects, promoting partnerships between project stakeholders (Lepczyk et al., 2017).

planning phase of construction projects (Chen et al., 2022).

Moreover, the three SDGs most referenced in the planning phase were SDG 7 ($n = 15$), SDG 6 ($n = 9$), and SDG 13 ($n = 9$). SDG 7 stands out as a primary focus in utilising AI to improve energy planning and management strategies. AI-powered tools can optimise energy systems, improve energy efficiency, and facilitate the integration of renewable energy sources (Saeed et al., 2022). Similarly, SDG 6 is central to AI-driven efforts in water resource management and conservation. AI technologies enable real-time monitoring of water quality, prediction of water-related risks, and optimisation of water distribution systems

(Cheng et al., 2010). Lastly, SDG 13, underscores the importance of integrating AI into climate resilience and adaptation planning processes. AI algorithms can analyse vast amounts of climate data, identify trends, and generate predictive models to inform decision-making to make project more sustainable (Pan et al., 2021).

4.3.2. Design phase

The design phase of a construction project is pivotal, serving as a central point upon which the project's success hinges. During this phase, crucial decisions regarding architectural concepts, structural and material specifications, and sustainability considerations are deliberated, significantly shaping the project's eventual outcome (Turner et al., 2020). A meticulously formulated design plan lays the groundwork for seamless implementation, facilitating efficient resource allocation and alignment with project objectives within specified constraints.

The examination of existing literature revealed 25 studies that highlighted the relevance of AI and SDG within the design phase. AI emerged prominently, mentioned 14 times, signifying its pivotal role in automating tasks, generating design alternatives, and simulating scenarios to optimise outcomes (Gálvez-Martos et al., 2018). ML was mentioned 7 times, highlighting its significance in processing extensive datasets, providing decision-making insights, and fostering design innovation. Despite DL receiving only 3 mentions, its algorithms remain instrumental in uncovering hidden insights and refining aspects such as structural integrity and energy efficiency in design (Chen et al., 2022).

Furthermore, the three most frequent mentioned SDGs in the design phase were: SDG 7 ($n = 12$), SDG 9 ($n = 11$), and SDG 6 ($n = 10$). SDG 7 is particularly noteworthy as a primary focus since AI can harness and optimise energy usage in building designs, using predictive modelling and energy simulation (Baduge et al., 2022). This entails analysing various factors such as building orientation, materials, and occupancy patterns. Similarly, SDG 9 was frequently mentioned for enhancing AI-driven design optimisation algorithms, enabling engineers to develop more resilient and sustainable infrastructure solutions. Additionally, BIM augmented with AI technologies enables collaborative designs and construction planning, facilitating better coordination amongst project stakeholders and reducing errors. Lastly, SDG 6 was frequently mentioned concerning AI integration, assisting in the design of water-efficient systems within buildings, optimising water usage through predictive analytics and smart monitoring devices. Moreover, AI algorithms can analyse large datasets from sensors and IoT devices to identify patterns and anomalies in water usage, enabling early detection of leaks and excessive water usage (Çetin et al., 2021).

4.3.3. Construction phase

The construction phase serves as a vital link between planning and design, translating sustainability goals into tangible structures. Inefficient practices during this phase can hinder green initiatives and waste reduction efforts, limiting a project's contribution to sustainability (Cheng et al., 2010). AI enhances project management, resource allocation, and construction workflows, ensuring alignment with SDGs. It acts as a catalyst for sustainable practices, preserving goals from planning to construction (Oluleye et al., 2022).

Upon reviewing the available literature, 24 studies were identified that emphasised the significance of AI and SDGs during the construction phase. AI featured prominently, being referenced 14 times, indicating its crucial role in automating tasks, generating design alternatives, and simulating scenarios to enhance outcomes (Bang et al., 2022). ML was mentioned 7 times, underscoring its importance in processing large datasets, offering decision-making insights, and promoting design innovation. Although DL was mentioned only 3 times, its algorithms continue to play a vital role in revealing hidden insights and refining elements like structural integrity and energy efficiency in design (Sev, 2009).

In addition, the top three most frequently mentioned SDGs in the construction phase were SDG 9 ($n = 17$), SDG 12 ($n = 18$) and SDG 13 ($n = 15$). SDG 9 stands out as a primary focus in the construction stage of projects, with AI playing a crucial role in enhancing design optimisation algorithms (Yaseen et al., 2020). By leveraging AI-driven solutions, engineers can develop resilient and sustainable infrastructure solutions. These advancements not only streamline construction processes but also contribute to long-term environmental and social sustainability. Similarly, SDG 12 emerges as another key area where AI integration in construction holds immense potential. Through innovative applications of AI technologies, such as predictive analytics and smart monitoring devices, construction projects can optimise resource utilisation, reduce waste, and promote sustainable consumption and production practices (Baduge et al., 2022). Lastly, SDG 13 and AI-enabled solutions offer opportunities to enhance resilience to climate-related risks, optimise energy usage, and mitigate carbon emissions throughout the construction stage (Zhang, 2021).

4.3.4. Operation and maintenance phase

The repair and maintenance stage of a construction project is crucial, acting as a cornerstone upon which the project's durability and longevity rely. Throughout this stage, essential tasks such as identifying repair needs, sourcing quality materials, and implementing sustainable maintenance practices are carefully considered, greatly influencing the project's ongoing performance (Klarim et al., 2023). A well-thought-out repair and maintenance plan establishes a solid foundation for effective execution, enabling the allocation of resources and adherence to project goals while navigating various constraints (Zhang et al., 2021).

The review of existing literature identified 16 studies that emphasised the importance of AI and SDGs during the repair and maintenance phase, although it was the least frequently mentioned phase. AI stood out prominently, being mentioned 12 times, highlighting its crucial role in automating tasks, generating design alternatives, and simulating scenarios to enhance repair and maintenance outcomes (Fayek, 2020). ML was cited 3 times, underlining its importance in handling large datasets, offering decision-making insights, and driving innovation in repair and maintenance procedures. Lastly, DL received only 1 mention, despite its potential in revealing hidden insights and refining aspects such as structural integrity and energy efficiency during repair and maintenance tasks (Ghimire et al., 2024).

Furthermore, the three frequently mentioned SDGs in the repair and maintenance stage were SDG 11 ($n = 12$), SDG 7 ($n = 10$), and SDG 13 ($n = 5$). SDG 11 was frequently highlighted as AI plays a crucial role in urban planning and infrastructure management to establish more inclusive, safe, resilient, and sustainable cities (Baduge et al., 2022). AI-driven solutions enable better resource allocation, optimised transportation systems, and enhanced disaster preparedness. Similarly, SDG 7 was frequently cited as AI technologies are vital in optimising energy usage within building designs, utilising predictive modelling and energy simulation (Araújo et al., 2018). Lastly, SDG 13 was often mentioned as AI integration assists in climate resilience and adaptation efforts, facilitating the development of infrastructure solutions capable of withstanding climate-related challenges. AI algorithms analyse data from sensors and IoT devices to identify climate patterns and mitigate risks (Pan et al., 2023).

5. Findings and discussion

Introducing AI into the construction industry to align with SDGs holds immense potential to revolutionise the sector, particularly in reducing its environmental footprint. The built environment plays a pivotal role in shaping the quality of life for individuals and communities, spanning from the initial planning and design phases to construction, repair, and ongoing maintenance (Opoku et al., 2019). Hence, it's imperative for the industry to remain adaptable and forward-thinking to meet evolving needs.

Creating a sustainable built environment with energy-efficient infrastructure is crucial for curbing energy demand and combatting climate change. AI-powered systems offer innovative solutions to optimise energy usage, minimise waste, and streamline resource allocation, ultimately leading to reduced carbon emissions and the preservation of natural resources (Pizzi et al., 2020). These advancements align with principles of environmental sustainability and promote a responsible, cost-effective approach to development. By harnessing AI technologies, the construction industry can accelerate progress towards SDGs, fostering a more sustainable and technologically advanced approach to building and infrastructure development, benefiting both the industry and broader society.

The correlation between construction-related SDGs is clearly demonstrated, as depicted in Fig. 7. By aligning with SDG frameworks, the construction industry has the potential to expand its impact. This interdependence underscores the pivotal role of the construction sector in advancing the global sustainability agenda. For instance, construction projects involving affordable housing, infrastructure development, and clean energy installations directly contribute to SDGs such as SDG 7, SDG 9, and SDG 11. Simultaneously, construction projects indirectly influence SDGs like SDG 5, SDG 14, and SDG 16 through factors such as labour practices, resource consumption, waste management, and the creation of safe buildings.

This interconnectedness underscores the importance of collaborative efforts, multi-stakeholder engagement, and holistic approaches in addressing global challenges. It emphasizes that achieving SDG requires integrated strategies that recognize and address the interdependencies amongst various goals. In essence, integrating AI into the construction industry not only drives progress towards SDGs but also underscores the importance of holistic, collaborative approaches in addressing complex societal and environmental challenges.

The convergence of SDG and AI is reshaping the landscape of the construction industry. This intersection represents a pivotal moment where traditional approaches to construction are being reimagined and redefined to align with the urgent need for environmental stewardship and resource efficiency.

Water and biodiversity management are critical aspects of sustainable development, with efficient water resource management being key to mitigating adverse effects on ecosystems and addressing land degradation, thus contributing to the objectives of SDG 6 and SDG 15. Through the integration of AI data-driven insights and real-time capabilities, the construction industry can actively contribute to environmental preservation (Froese et al., 2007). Construction and demolition processes often involve significant water usage, leading to runoff that affects water resources. By harnessing AI technology, the construction sector can reduce excessive water consumption, enhance water management practices, and mitigate environmental impacts (Opoku et al., 2019).

The reduction of waste and effective energy management are pivotal for advancing SDG 7 and SDG 12, which aim to facilitate clean energy access and minimise waste generation in construction activities. The integration of Building Information Modelling (BIM), Internet of Things (IoT), and predictive systems enhances the industry's efficiency, sustainability, and safety, pushing its capabilities forward. AI integrated into construction processes can address environmental challenges associated with waste generation, particularly from construction and

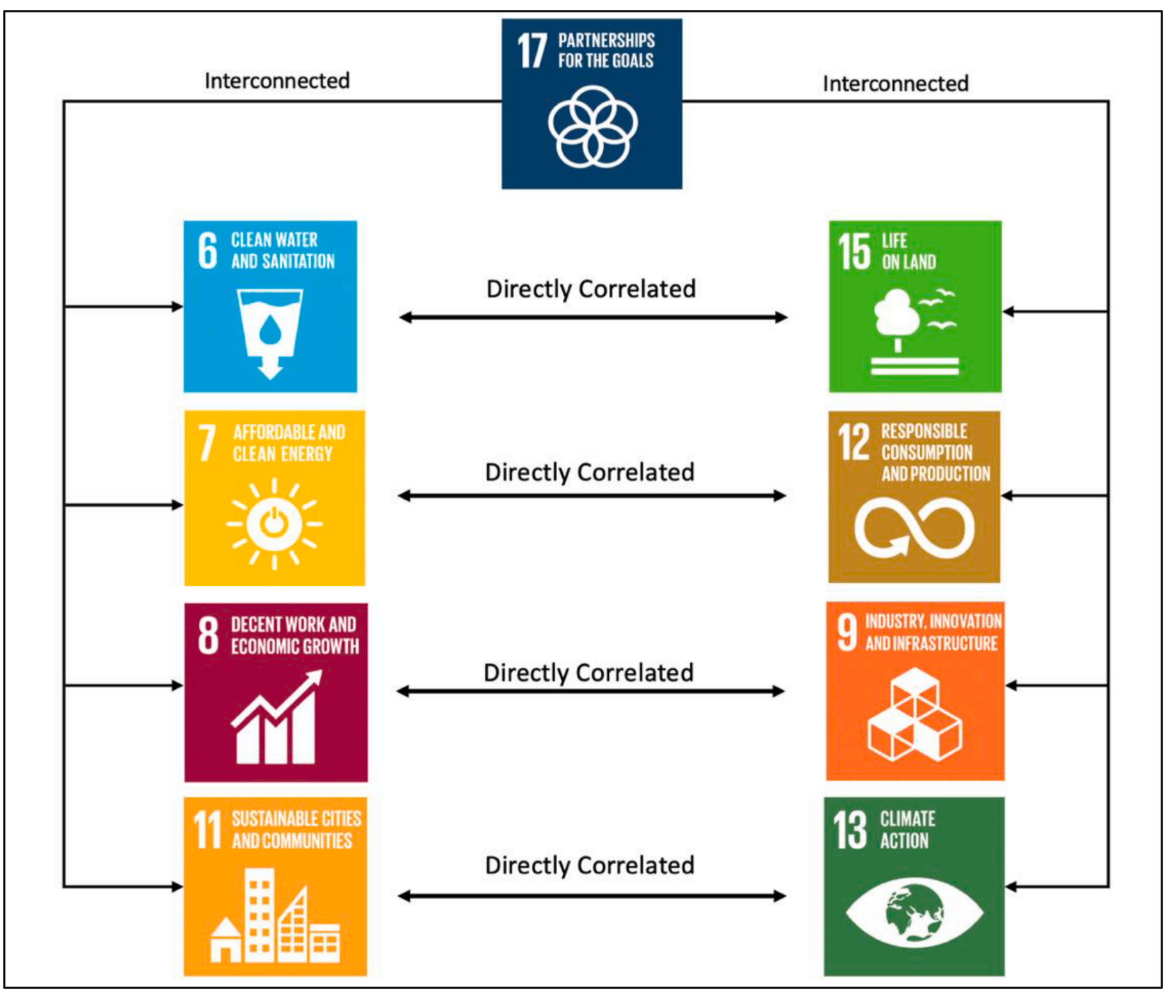

Fig. 7. A direct relationship between SDG signifies a clear correlation between two specific SDGs. The importance of AI in the construction sector to achieve SDG can be broken down into several key aspects.

demolition activities (Dickens et al., 2020). AI-driven measures play a crucial role in waste reduction, promoting material reuse, optimising resource efficiency, fostering sustainability, and mitigating environmental harm.

Innovative resource management is fundamental to the success of sustainable construction, relying on a combination of economic growth, reliable infrastructure, and innovation. Predictive analytics, supply chain optimisation, and improved communication efficiency empower organisations to increase profit margins and drive innovation (Gao, 2020). Strategic implementation of predictive analytics, AI-driven supply chain optimisation, and data-driven communication enhances sustainability efforts, aligning with SDGs 8 and 9, which promote economic growth, decent work, and technological progress.

Safety and environmental preservation are paramount considerations for construction companies undertaking large-scale sustainable projects in rapidly growing urban areas (Mortoja et al., 2020). AI is leveraged to enhance various facets of construction, resulting in increased efficiency and sustainability (Goubran, 2019). The integration of AI facilitates the delivery of essential services such as healthcare, water, and energy to communities while also reinforcing low-carbon systems within circular economies and smart cities, optimising resource utilisation in alignment with SDG 11 and SDG 13.

The importance of AI in the construction industry as a driver of SDG cannot be overstated. With its transformative capabilities, AI serves as a cornerstone in this transformative journey. It promises to reshape how projects are planned, designed, constructed, and managed (Naser, 2019). Therefore, making projects more efficient, resource-conscious, and environmentally responsible. AI's integration into the construction industry is not just a technological advancement; it's a strategic pathway to achieving SDGs (Ginzburg et al., 2018).

AI's impact on construction extends beyond operational enhancements; it encompasses a holistic approach towards sustainability and resilience. Through the reduction of resource consumption, minimisation of waste generation, fostering of innovation, and enhancement of safety measures, AI plays a pivotal role in steering the construction industry towards a more sustainable and resilient future, both in the short and long term (Opoku et al., 2022). Recognising AI as a critical tool in this transformative journey is imperative. It must be embraced and harnessed effectively to ensure the betterment of society and the preservation of our planet for future generations.

Table 20
Primary application of AI algorithms and its potential to revolutionise the current construction industry.

Application	Description
AI-driven automation	By automating tasks like project scheduling, material procurement, and resource allocation, AI reduces human error and optimises efficiency. This streamlining not only saves time and costs but also minimises resource waste, contributing to sustainable practices (Hsu et al., 2020).
Predictive analytics	Predictive analytics leverage AI algorithms to forecast project outcomes and identify potential risks. By anticipating challenges such as delays or budget overruns, construction teams can take proactive measures to mitigate these issues, thus reducing resource waste and promoting project sustainability (Kumar et al., 2019).
Computer vision technology	Computer vision enhances monitoring and quality control on construction sites by detecting deviations from project specifications in real-time. Early identification of errors minimises rework and material wastage, ultimately leading to more sustainable construction practices (Lin et al., 2021).
Robotics and autonomous machinery	AI-driven robotics and autonomous machinery perform tasks with precision and efficiency, reducing the need for manual labour. This not only improves productivity and safety but also minimises resource consumption, contributing to sustainable construction practices (Ma et al., 2019).
Data analytics	AI-enabled data analytics optimise resource utilisation and energy efficiency by analysing data from various sources such as building sensors and weather forecasts. By identifying opportunities to reduce energy consumption and optimise resource usage, construction projects can minimise their environmental footprint and promote sustainability (Nilsson et al., 2016).
Early error detection	AI-driven technologies enable early detection of errors and deviations from project specifications, reducing the need for rework and minimising resource waste. By addressing issues promptly, construction projects can maintain their schedules and budgets while promoting sustainability (Omer et al., 2020).
Real-time insights	AI provides real-time insights into project performance, enabling proactive decision-making. By identifying inefficiencies or risks as they arise, construction teams can take timely actions to address these issues and minimise their impact on project sustainability (Opoku et al., 2022).

5.1. Key findings

The articles acknowledge AI's pivotal role in advancing sustainability within projects and its transformative impact. AI functions not only as a catalyst but also as a guiding influence, reshaping conventional methodologies and approaches to conform with sustainable practices as seen in Table 20.

The literature highlighted the data-driven and predictive capabilities that AI can bring to a project, which will optimise resource allocation, streamline processes, and enhance decision-making. Using these capabilities and allowing organisations to monitor and manage tasks will contribute immensely to reaching sustainable objectives. Furthermore, AI's role in enabling projects to adapt and respond to evolving sustainability challenges (Pizzi et al., 2020). It pointed out how AI-driven technologies such as ML and natural language processing can enhance the collection and analysis of sustainability data, enabling proactive and data-informed responses to emerging issues. AI can also improve supply chain efficiency, workforce productivity, and stakeholder engagement (Saeed et al., 2022). Therefore, contributing to broader sustainability goals and broader context of sustainable development as see in Table 21.

Out of the 91 papers that were reviewed, a discernible distribution was observed based on a clear focus across different phases of the construction process. Specifically, 21 papers (23 %) delved into topics pertinent to the planning phase, encompassing strategic pre-construction considerations. Similar, 25 papers (27 %) addressed the design phase, examining architectural and engineering aspects fundamental to project conceptualisation. Furthermore, 27 papers (30 %) provided insights into the construction phase, exploring methodologies, technologies, and practices deployed during project execution. Lastly, 18 papers (20 %) were primarily dedicated to the operation and maintenance phase, highlighting post-construction activities aimed at ensuring sustainable upkeep and longevity of built structures. This distribution reflects the diverse focus areas within the construction domain explored by the reviewed literature.

The analysed papers also provided an insight into the relevant SDGs where the construction industry can significantly contribute and make a substantial impact to improve sustainability. Out of the 169 targets outlined in SDGs, 70 (41.42 %) are pertinent to the construction sector. amongst these, 18.34 % are directly influenced by construction projects, while 23.07 % are indirectly affected by the construction industry, as seen in Fig. 8.

The construction industry requires different stakeholders to expand their scope of action beyond environmental attributes. Therefore, organisations that apply SDG principles to their framework must recognise substantial and positive links between targets and indicators. Organisations must also implement learning methods that embrace sustainability and innovation. Traditional approaches like post-project reviews (PPRs) and post-occupancy evaluations (POEs) in construction focus on

Table 21
Key AI uses in a construction project to promote SDG derived from Chen et al. (2022).

Sustainability Pillar	Description
Environmental	• *Energy Optimisation:* Real-time monitoring lowers energy consumption and emissions. • *Material Selection:* AI minimises material waste by optimising usage. • *Water Management:* AI powered system that can identify opportunities for conservation improvements. • *Renewable energy integration:* Optimise the integration of renewable energy sources. • *Environmental impact assessment:* Identify potential risks and suggestion to minimise the harm on ecosystems. • *Green Building Design:* AI assists in designing eco-friendly structures. • *Waste Management:* AI improves waste reduction and recycling efforts.
Social	• *Safety Monitoring: AI enhances worker safety by identifying hazards in real-time.* • *Labour Optimisation: AI optimises labour allocation for fair and efficient scheduling.* • *Training and Development: AI-driven platforms personalise learning for skill enhancement.* • *Community Engagement: AI fosters transparent communication with local communities.* • *Diversity and Inclusion:* AI aids in improving workforce diversity and inclusivity.
Economic	• *Project Planning: AI optimises schedules and resource allocation, reducing costs.* • *Cost Estimation: AI provides accurate budget forecasts, aiding financial planning.* • *Supply Chain Optimisation: AI streamlines procurement processes, minimising waste and costs.* • *Productivity Monitoring: AI tracks worker and equipment efficiency in real-time, optimising workflow.* • *Predictive Maintenance:* AI predicts equipment failures, reducing downtime and repair costs. • *Performance* Analytics: AI analyses project metrics to improve productivity and profitability.

technical aspects, overlooking the broader social, economic, and environmental impacts. These reviews should become routine and encompass non-technical aspects related to the SDGs. Additionally, companies must prioritise directing resources towards policies and programs that can make a substantial positive impact and generate sustainable development outcomes.

5.1.1. Direct influence on sustainable development

AI has emerged as a catalytic force within the construction sector, reshaping traditional practices and ushering in an era of unparalleled efficiency and sustainability. The applications of AI within this industry serve as transformative tools, revolutionising every facet of construction processes (Ma et al., 2019). At the core of AI-driven applications lies its ability to streamline workflows with unprecedented precision. By leveraging sophisticated algorithms and machine learning capabilities, these applications meticulously analyse vast datasets, identifying patterns and optimising workflows. This not only expedites project timelines but also significantly reduces inefficiencies, thereby saving time and costs (Regona et al., 2022a).

Moreover, the impact of AI extends well beyond mere efficiency gains. These technologies have become integral in enhancing project management practices. AI-powered project management tools offer comprehensive insights and predictive analytics that empower decision-makers to make informed choices (Rakesh et al., 2023). The ability to foresee potential hurdles, optimise resource allocation, and adapt plans in real time ensures projects stay on track, meeting deadlines and budgetary constraints more effectively. Safety within the construction industry has perennially been a paramount concern. AI applications are instrumental in fortifying safety protocols. Through the amalgamation of AI with IoT sensors and real-time monitoring systems, construction sites can proactively detect and mitigate safety risks. Machine learning algorithms analyse historical data to predict potential hazards, thereby fostering a safer work environment and minimising accidents (Wang et al., 2023).

Furthermore, the optimisation of resource allocation stands as a cornerstone of sustainable construction practices. AI-driven applications excel in this domain, facilitating precise project planning and predictive maintenance. Predictive analytics models anticipate maintenance needs, optimising equipment usage and reducing downtime. Real-time monitoring not only aids in tracking resource utilisation but also enables timely adjustments, contributing to reduced waste and enhanced sustainability (Bang et al., 2022). This alignment of AI technologies with SDGs is not incidental but rather a strategic synergy. By fostering precise project planning, predictive maintenance, and real-time monitoring, these technologies directly support SDG targets related to sustainable infrastructure, resource efficiency, innovation, and safe working environments (Alsakka et al., 2023).

5.1.2. Indirect influence on sustainable development

The influence of the construction industry spans a vast spectrum of critical aspects that significantly impact global sustainability efforts. From resource consumption to energy efficiency, job creation, and economic growth (Zeng et al., 2023). Through a concerted focus on sustainable construction practices, the adoption of eco-friendly technologies, and the steadfast adherence to responsible business ethics, the construction industry possesses the potential to significantly amplify their indirect contributions to the overarching goal of sustainable development.

Simultaneously, the influence of AI extends its reach, indirectly catalysing progress toward sustainability objectives. AI-driven innovations serve as pivotal agents in curtailing resource waste, enhancing energy efficiency, and mitigating environmental impacts. By enabling data-driven decision-making processes, these technologies empower stakeholders to make informed choices that optimise resource utilisation and minimise waste across various operational facets within the construction industry (Statsenko et al., 2022).

Moreover, the integration of AI does not just streamline processes; it also fosters a more inclusive and engaged community. Through enhanced stakeholder engagement facilitated by AI technologies, there emerges a platform for broader societal inclusion. This inclusion extends beyond economic facets, advancing educational opportunities and skill development. AI's role in promoting learning platforms and accessible educational resources contributes to a more knowledgeable and adaptable workforce, ultimately bolstering social welfare and fostering greater community resilience (Wahbeh et al., 2020).

Furthermore, AI's impact on the construction industry echoes in the development of more resilient and community-centric urban environments. By leveraging AI-driven insights, urban planning becomes more responsive and adaptable to the needs of communities. This creation of sustainable urban landscapes that prioritise the well-being of residents, promote social cohesion, and optimise resource allocation within these environments (Turner et al., 2020). In this cohesive interplay between the construction industry and AI technologies, the indirect contributions to sustainability initiatives become evident. This proactive approach not only aids in mitigating potential risks but also paves the way for the symbiotic relationship intertwines economic prosperity, ecological stewardship, and social well-being, forging a path toward a more equitable and sustainable future (Singh et al., 2023a).

5.2. Research contributions

The integration of AI into the construction industry to achieve SDGs represents a transformative approach with the potential to revolutionize project planning, execution, and management. The systematic literature review stands out in the discourse on AI's role in advancing SDGs within

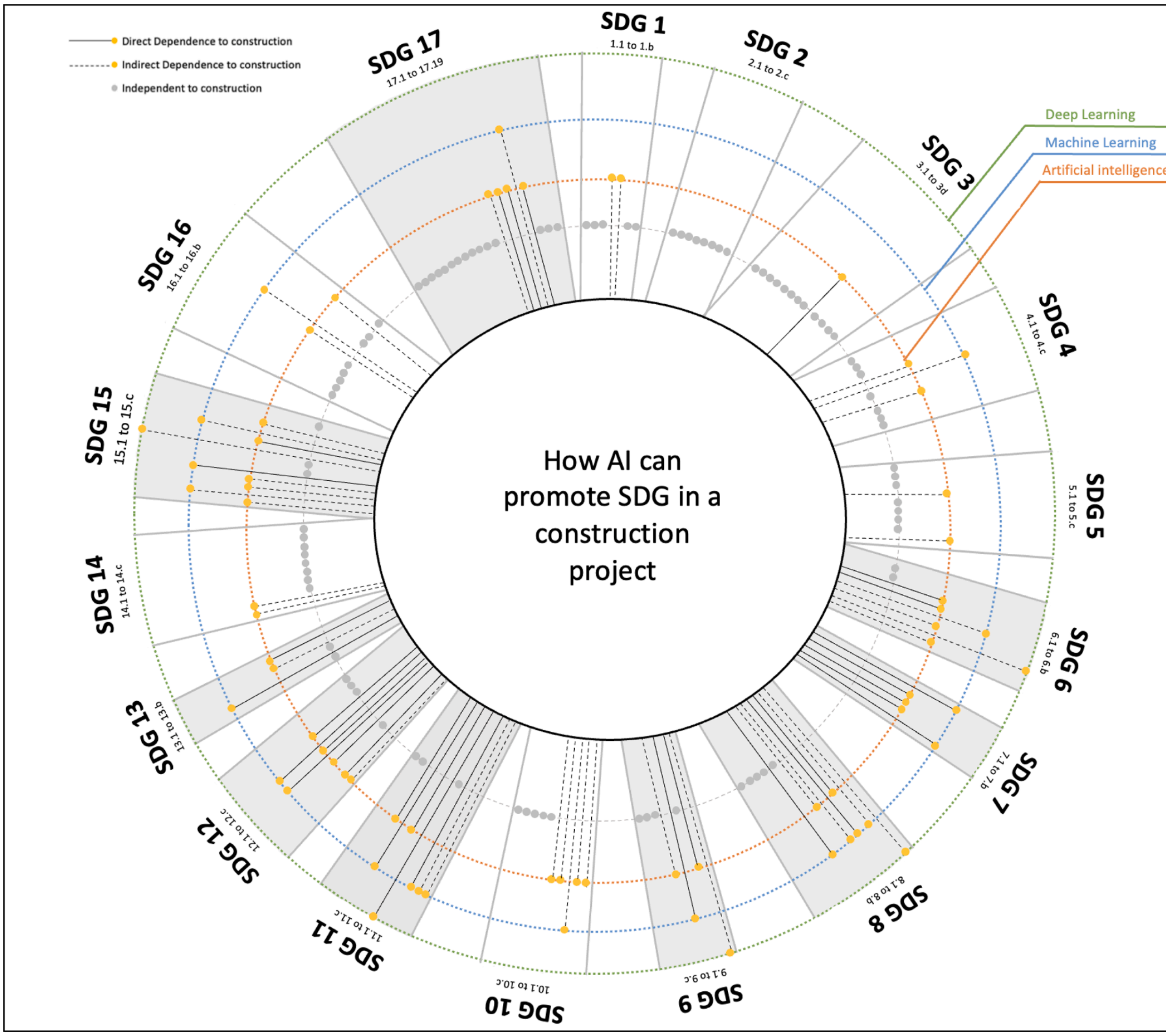

Fig. 8. A visual map of the dependency of SDGs on construction activities. Targets are ordered clockwise and distributed amongst sub-categories of AI. Additionally, the SDGs highlighted in grey signify crucial SDGs that AI can significantly impact.

construction. Unlike recent studies focusing solely on specific AI technology that impacts sustainability, this literature review conducts a comprehensive examination of current AI applications and their impacts across all construction stages. It identifies various AI subsets, discussing their adaptability to construction and potential contributions to sustainable development. Moreover, it specifies the most relevant SDGs for construction, illustrating how AI can enhance sustainability considerations effectively and efficiently. Ultimately, it offers crucial guidance for researchers and practitioners aiming to harness AI for sustainable development in construction.

The findings were derived from the 91 papers and formed nine directly correlated SDGs that can help stakeholders achieve more sustainable projects. These identified SDGs promise to guide stakeholders in the construction industry toward the realisation of more sustainable projects. The technologies subject to examination are delimited to those operative within the distinct phases of planning, design, construction, and subsequent repair and maintenance processes. As AI in construction is a relatively new concept and there is limited knowledge on the importance of AI to help projects meet SDGs, the contributions of this paper are as follows:

- A new body of knowledge concerning the significance of AI in facilitating a shift from traditional approaches to construction practices that align with the SDGs.
- An understanding of existing applications that can help stakeholders achieve the nine relevant SDGs.
- Emphasises that AI will be pivotal in achieving sustainability within the construction industry.
- Provide a comprehensive and detailed insight into the application of AI, ML and DL for achieving the identified SDGs within the construction sector.
- Acknowledges the existence of substantial research gaps in the field, emphasising that there needs to be more comprehensive investigations that specifically examine the impact of AI on SDGs within the context of the construction industry.
- A review of the opportunities and challenges that the construction industry encounters when they implement AI to achieve SDG.
- A groundwork for future research based on furthering the understanding of directly correlated SDGs.

Based on the insights derived from this paper, future research endeavours will continue to explore the challenges related to the adoption of AI, as well as the potential opportunities it offers for the construction sector.

5.3. Research limitations

The study has the following limitations: (a) The study relied on 91 selected papers, which may only partially represent the diverse array of global construction projects. The specific contexts and characteristics of different regions, project scales, and construction practices may not be fully captured; (b) Additional literature reviews to expand on the current findings and develop a better understanding of the opportunities and challenges of implementing AI technologies to promote SDG; (c) No data was collected. The paper did not conduct interviews with on-site professionals to capture their insights on the application of AI throughout a building's lifecycle in support of SDG; (d) The process of identifying and correlating nine SDGs may be subject to interpretation and bias. Different stakeholders may prioritise other SDGs based on their perspectives, potentially influencing the applicability of the findings; (e) The examination of technologies within a specific phase of construction may not encompass the full range of the construction industry. Consequently, variations in practices across different sectors within the industry may need to be fully addressed; (f) Given the dynamic nature of AI in construction, specific technologies and methods may become obsolete over time. The continuous evolution of technology could impact the ongoing relevance of specific findings; and (g) While the paper acknowledges challenges in implementing AI for SDGs in construction, a more in-depth exploration of these challenges, along with potential mitigations, could provide a better understanding. In conclusion, while the contributions of this paper are significant, these identified limitations highlight areas for further research refinement and expansion to enhance the robustness and applicability of insights within the dynamic landscape of AI integration in the construction industry.

5.4. Future scope

The findings of this research hold significant promise for the future trajectory of sustainable construction practices. By shedding light on the intricate interplay between technological innovation, notably AI, and the attainment of SDGs, this study lays the groundwork for advancements in the construction industry. The incorporation of AI-driven solutions holds the potential to revolutionise various stages of construction projects, ranging from initial design phases to execution and ongoing maintenance, by streamlining resource allocation, bolstering operational efficiency, and curtailing ecological footprints. Going forward, industry stakeholders can harness the actionable insights gleaned from this research to strategically deploy AI technologies, thereby expediting progress towards sustainable development objectives while fostering a culture of ingenuity and stewardship within Australia's construction sector.

6. Conclusion

This study has systematically reviewed the literature on AI in the construction industry using the PRISMA protocol. The study findings highlight the construction industry's importance in capitalising on the potential of AI across the entire project lifecycle, steering the industry towards practices that align with sustainability goals (Young et al., 2021). The increasing complexity of modern construction is now the main driver for developing interest in AI Given the industry's substantial energy consumption; it assumes a pivotal role in advancing sustainability (Statsenko et al., 2022). By identifying and correlating nine SDGs through the analysis of 91 articles, this paper provides a roadmap for stakeholders to guide their efforts towards more sustainable construction projects. The contributions of this research extend beyond the identification of SDGs; it has created a new body of knowledge highlighting the significance of AI in transitioning from traditional construction approaches to practices aligned with SDGs. The paper explores existing applications and emphasises AI's pivotal role in achieving sustainability. Governments should utilise the construction industry as a driving force by implementing effective policies and regulations. Collaborative efforts between government agencies and stakeholders are essential for integrating the SDGs into long-term business strategies and advancing sustainability (Dickens et al., 2020).

This paper establishes a foundation for future research initiatives by acknowledging existing research gaps and emphasising the need for more comprehensive investigations specific to the impact of AI on SDGs in the construction context. It reviews current opportunities and challenges in implementing AI for SDG achievement in the construction industry. It sets the stage for continued exploration into the hurdles associated with AI adoption and the untapped potential opportunities it presents. As technology advances, the construction sector will likely see further innovations and the adoption of new tools and techniques to meet evolving challenges and requirements. As the construction industry moves forward, future research efforts should persist in delving deeper into the challenges hindering AI adoption in construction while exploring its vast opportunities. By expanding our understanding of the interplay between AI and SDGs in construction, we can contribute to a more sustainable and technologically advanced industry that aligns with global development goals. The urgent call for collective action in the construction sector is not just about achieving goals; it's about shaping a sustainable and resilient future for future generations.

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CRediT authorship contribution statement

Massimo Regona: Writing – original draft, Formal analysis, Data curation. **Tan Yigitcanlar:** Writing – review & editing, Supervision, Conceptualization. **Carol Hon:** Writing – review & editing, Supervision. **Melissa Teo:** Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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