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The Role of Artificial Intelligence and Machine Learning in Enhancing Construction Projects

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Abstract:
This research project focuses on how machine learning and artificial intelligence help with different stages of construction projects. It is feasible to reduce hazards, estimate expenses more precisely, and even build sustainable structures through machine learning. The study also highlights how artificial intelligence excels at analyzing massive amounts of data to better plan and carry out projects in general, foresee problems, and distribute resources in the most efficient manner. The use of AI and machine learning technology is causing a significant transformation in the building industry. The building industry is changing due to the integration of machine learning and artificial intelligence. By monitoring construction sites and identifying threats early, AI-powered solutions also increase safety. Artificial intelligence and machine learning algorithms enable prompt decision-making, improve safety procedures, maximize resource usage, and offer predictive analytics. These solutions increase efficiency and lower risks by using big data to identify future project delays, cost overruns, and equipment breakdowns. The results show that those involved in building projects are looking for artificial intelligence tools to help with quantitative processes, especially those related to risk management, quality control, scope, schedule, and cost. AI-driven automation is also encouraging creativity, increasing productivity, and simplifying monotonous chores. This article focuses on how artificial intelligence and machine learning have significantly contributed to construction projects to produce more intelligent, sustainable building processes. It emphasizes challenges and outlines potential future integration options for these technologies. Finally, the article underlines the revolutionary power of artificial intelligence and machine learning in building. It is paving the way for a future in which the built environment is more efficient, safe, and sustainable. The research presents an academic contribution by conducting a complete literature review, categorizing artificial intelligence and machine learning applications based on the life cycle of a building project, and identifying suitable deployment sites at various stages.
Key Words: Artificial Intelligence, Machine Learning, Construction Projects, Project Management, Sustainable Construction, Real-Time Decision-Making, Digital Readiness

Introduction:

Construction projects that require a lot of manual work often develop time and cost overruns and have, over time, embraced technological change that improves project performance and results. Of these technologies, AI and ML are perhaps the most revolutionary in terms of their

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applicability. These innovative technologies are on the cusp of transforming the construction industry since they enhance the decision-making process, resource management, safety measures, and timely delivery of projects. AI and ML systems are used in construction for predictive analysis, design automation, site monitoring, and analysis, all of which hold potential for improving the construction work flow and efficiency of the process (Oesterreich & Totenberg, 2016). AI and ML enable predictive analysis, whereby an organization can identify problems before they occur and reduce risks and their impacts on the business. For instance, it involves the use of algorithms to determine the most likely time that a project would take, how much money it would require, and the likelihood of a bottleneck. These proactive measures assist in dealing with the unpredictability of delays and additional costs, which are typical of construction projects (Shokravi et al., 2020). Besides this, machine learning models are capable of learning from data and tend to get better over time by refining their forecasts. Resource allocation is one of the biggest areas that could benefit from the use of AI and ML in construction. In construction projects, resource management has been cited as a major problem that contributes to the wastage of resources such as materials and labor. AI can assess project needs and the available resources to determine the best ways of utilizing the material, tools, and manpower resources. This not only minimizes waste but also increases efficiency and profitability (Pan & Zhang, 2021). Another crucial domain that has greatly benefited from AI and ML is safety. Construction sites are inherently dangerous, and they involve many risks to the lives of construction workers. Real-time supervision by AI can help analyze construction areas for safety risks and alert the supervisor to take necessary actions. For example, with the help of computer vision, one can identify laxity issues like not wearing protective gear or faulty equipment and prevent accidents (Zhou et al., 2018). Furthermore, safety self-learning algorithms can be employed to assess past accidents and forecast possible safety issues in the future to institute proper measures. On that same note, AI and ML are handy tools that enhance the quality and accuracy of the construction work done. This approach suggests that with the use of AI in the design and planning of construction projects, structural and infrastructural designs and plans can be developed with great detail and accuracy. Some of them may even create custom models, allowing architects and engineers to select the best solutions from a range of scenarios and options. Such level of detailing helps eliminate discrepancies and requires less time to accomplish the work, thereby producing higher-quality results, as pointed out by Li et al. (2019). Beyond design and planning, AI and ML transform operations at sites too. Self-propelled equipment and robotic systems powered by artificial intelligence can sort and enumerate objects faster and with less human error as compared to human operators. For instance, intelligent drones can perform tasks such as site review, assessment of progress, and review of difficult-to-access sections, among others, since they can relay information in real-time. While doing so, it enhances productivity because it frees the human workers from doing menial tasks that may even be boring to them, enabling them to do more of the important tasks, thus improving productivity (Bock & Linner, 2016). At the same time, the use of AI and ML leads to improved communication and cooperation between project participants. Using AI, one can bring together data from different sources and have a single point of access to the most important information about the status and progress of the project. This enhances more informed decision-making as well as coordination between architects, engineers, contractors, and clients. Effective communication removes gaps and mistakes, hence improving the flow of project delivery and increasing client satisfaction (Teizer et al., 2017). AI and ML are also being employed in the

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construction industry towards sustainability objectives. Through integration with offsite manufacturing, AI creativity can enhance the effective use of materials and energy in construction. Such machine learning models could interpret environmental data to plan and develop green buildings and structures that conform to green standards. Furthermore, AI can aid in the correct sorting of waste and recycling of materials, leading to increased sustainable construction solutions (Carbonari et al., 2018). However, the adoption of AI and ML in congestion is not without its problems. Aspects like data privacy, the cost of implementation, and the brain power required to manage those technologies remain important. However, the prospects are much more significant, which is why AI and ML are among the most valuable tools that will shape the construction industry in the future. These technologies only increase their effect on construction projects, leading to smarter, safer, and more efficient construction practices (Khosrowshahi & Arayici, 2012). In the past, academics and investigators have published articles that review the use of AI and its branches in approaching specific problems pertinent to construction projects. However, there is a significant gap in research specifically focusing on the application of AI and ML in the construction life cycle. The present study investigates the literature thoroughly, focusing on the principles of AI and ML in the given construction project environment and the current state of their application. The justification for constructing a review article in this field originates from the identification of a specific gap in the literature. Artificial intelligence and machine learning are used in many ways for construction projects, but there is no proper classification of how these techniques can be applied at each stage of the construction project life cycle. The purpose is to review the existing literature to outline the key concepts of AI and ML, as well as the state of the art of applying these concepts in the construction sector. In more detail, the paper seeks to offer a thorough evaluation of their application across various project stages and contribute to the practical understanding of utilizing such intelligent systems in the construction industry. Therefore, the main purpose of this research is to present a detailed analysis of how AI and ML are implemented in the different project lifecycle stages in constructing projects, specifically to offer insights regarding the proper incorporation of these smart systems in the construction industry. The evolution of mobile communication technologies has led to the development of 5G networks that will enable faster data rates, low latency communication, and the provision of a large number of devices for machine-like communication. Two constructs of the current development of 5G include the Software Defined Network (SDN) and the Network Functions Virtualization (NFV) that provide flexible, scalable, and efficient management of networks. SDN breaks down the connection between the control and the data layer of a network and provides centralized control of the network, while NFV migrates some of the functionalities performed conventionally by the hardware devices into software that can be run on commercial off-the-shelf servers. This paper compares and analyzes the role of cloud-based SDN and NFV in 5G networks, with a focus on advantages, disadvantages, and their integration into the 5G network architecture to improve network performance and flexibility (Nawaz, Ali, Rai, and Maqsood, 2024). Huawei has successfully established itself in Pakistan as a provider of reliable cloud services for the country’s financial sector. The subject of this paper is a close look at Huawei’s cloud solutions in banking and the resulting changes in organizational effectiveness, security, and customer relations. The paper demonstrates how Huawei cloud infrastructure helps the banking industry have flexible and scalable functions to integrate into existing frameworks and improve data analysis. Besides, it describes the potential benefits of implementing Huawei cloud solutions for business, including decreased expenses for operations

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and increased compliance with the regulation. Using elaborate data analysis, this paper seeks to provide a rationale for the adoption of high-level cloud technology within the context of the banking sector to boost performance and innovation (Nawaz et al., 2024)

Figure No 01: Identification of studies via Database

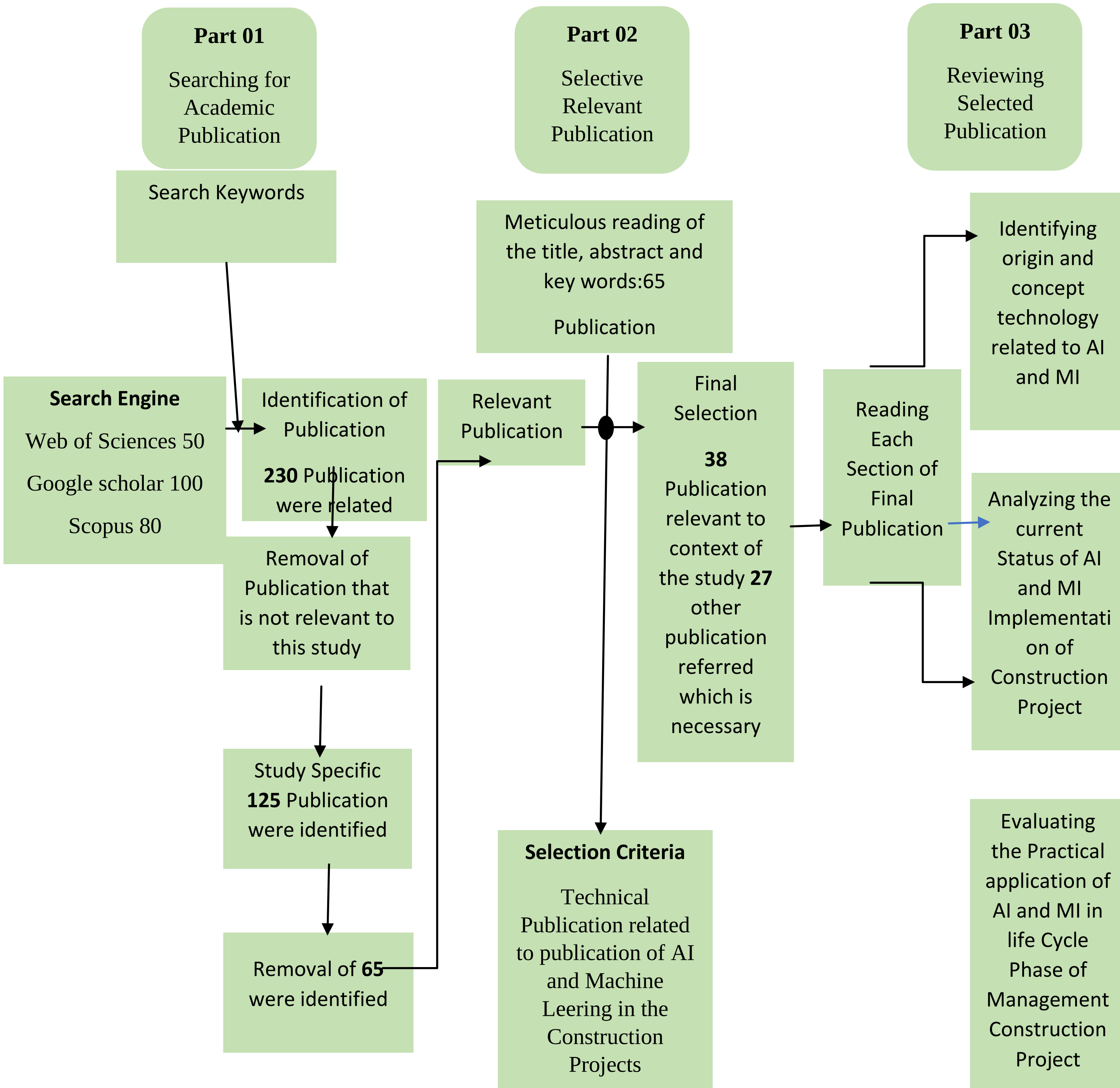

Figure No: 02 Documentation Retrievals

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Documentation Retrievals

Documentation inclusion and exclusion

	Google Scholar	Web of Sciences	Scopus
AI and MI for Management construction projects	N:100	N:50	N:80
Total	N:100	N:50	N:80

Document's profiling

Roles of AI and MI Learning in Enhancing Construction Projects

Content Analysis

Conclusion and Future Trends

Methodology:

Machine learning and artificial intelligence can be used to forecast future problems that are likely to affect the timeline, budget, or resources allocated for a certain project. Wang, S., Wang, H., Ge, Y., & Zhang, H. (2016). There is now a chance for computer-aided software to produce and fine-tune construction timetables, thereby cutting costs and human mistakes. Tian, C., and Teizer, J. (2013). AI algorithms can be used to specify building designs in terms of energy efficiency, structural robustness, and economic feasibility. Caldas, L. G., & Norford, L. K. (2002). Real-time safety measures can also be provided by machine learning models to evaluate data from the sensors and cameras to determine the presence of safety risks. Fang, W., et al. (2020). With the help of artificial intelligence, various robotic forms can be used to undertake monotonous and risky tasks on a construction site. Bock, T., and Linner, T. (2015). They can be utilized in the development of smart materials that change their features based on certain stimuli, like temperature or stress. Sihn, S., and Song, W. (2019). The information derived from ML algorithms can help determine which concrete mixtures have the requisite characteristics of strength and durability. undefined with AI, it also becomes possible to manufacture self-healing materials that can repair damages and cracks on their own. Van Belleghem, B., et al. (2018). AI can improve the performance of 3D construction materials by controlling the 3D printing process parameters and increasing the level of accuracy and material characteristics. Bos, F. P., et al.

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(2016) In this study, to conduct a rigorous review of a sufficient number of papers that are relevant to the specified domain of this research, a three-part approach was used. This involves the identification of appropriate literature through searches in different databases, the exclusion of unwanted material, and the evaluation of the remaining literature.

Searching for academic publications

Numerous scientific articles are available for access through online databases, such as Google Scholar, Science Direct, Scopus, and Web of Science. The writers employed the Boolean search terms in the article title and abstract search keywords to get an extensive list of papers. Artificial intelligence, machine learning, computer vision, automated planning and scheduling, and natural language processing were all mentioned in the first section. "Construction," "construction projects," "construction engineering," "construction management," and "construction engineering & management" were all included in the second section. To ensure broad coverage of the topic, the time filter was set between 2010 and 2024 since the use of AI and ML is still relatively new in the construction industry. Besides, no journals were selected with the aim of excluding a certain number of papers from being found. Because the most authoritative and popular sources were to be chosen, the document type was defined as ‘article’ or ‘review’. First, a Google Scholar search was made with keywords; this search yielded 121 results. To try to retrieve a more diverse number of articles, the authors added sources from both Scopus and Web of Science, and the final total was 230 articles. The exclusion of all non-relevant publications yielded 125 sources, including journals and conference papers. Each one of them was scrutinized according to how closely related it was to the construction industry; this saw some publications thrown out because they had no relation to construction at all. In this phase of the study, it is found that the following journals come out with three or more papers. Automation in Construction, Journal of Construction Engineering and Management, Engineering Applications of Artificial Intelligence, International Journal of Construction Management, and Journal of Building Engineering Advanced Engineering Informatics By this stage, the number of papers collected was 195, from 33 various sources, including research papers and conference proceedings.

Selecting relevant publications

In the second part, the author reviewed 62 publications that were included in Part 1 for an in-depth analysis. This stage aimed to find articles that addressed the specific topic of the investigation. To identify these papers, the authors read the titles, abstracts, and keywords of 65 papers and selected only those most closely related to the topic. At this level, it was possible to identify 38 papers that the authors regarded as relevant for this kind of study. Scholars quoted in the publications that were excluded based their results on theories of machine learning; these papers were therefore not included in the study. Some papers covered theories of application of artificial intelligence in phases of the construction project life cycle, and therefore the publications were excluded. It was also aimed at publications that at least tried to enhance the conventional building system in some phases of a project. The authors also censor if the publication describes the same applications. Here is the most recent option to select, which is the best choice in terms of its applicability, cost, and time factors prevailing in the context. It also enables project colleagues to just exclude or include the application of various phases in building.

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Reviewing selected publications

The author concentrated on content analysis in this phase in order to determine how AI and ML emerged, what principles underpin them, and what technological advancements related to AI and ML. Similarly, the review sought to comprehend the current practices and applications of AI and ML in construction projects by emphasizing insights from the chosen articles.

Artificial Intelligence

The earliest creation stories and artificially intelligent beings are where the idea of artificial intelligence originated. Artificial intelligence has only become more advanced in the last century. In the early years, artificial intelligence tried to mimic human classifications and knowledge in a more or less explicit manner. These include John McCarthy's contribution throughout the development of the Linux programming language and Marvin Minsky's work on Perceptron. This was the beginning of the so-called 'expert systems', oriented towards emulating the decision-making capacity of a human expert. The shortcomings of these systems contributed to what became known as the "AI winter," a time of lower funding and enthusiasm for the field. The emergence of large-scale computations, the convenience of obtaining vast datasets, and ML's improvements breathed new life into the AI field. Some of the success stories include IBM Deep Blue beating chess champion Garry Kasparov in 1997 and the shift towards statistical models in AI.

Machine Learning

Artificial intelligence can be categorized into three categories: Machine learning: This is a technique through which algorithms for computers are designed to learn from data in order to make certain predictions. Machine learning has been recognized as closely related to areas such as artificial intelligence, statistics, and data mining. The perceptron was proposed by Frank Rosenblatt in 1958; however, it is a neural network model, which is the basis of most modern models of machine learning. 1950s–1960s: This concept preceded the modern machine learning approach and was an homage to the perceptron and early neural networks. However, their limitations, especially in solving non-linear problems, were discovered later, as pointed out by Marvin Minsky and Seymour Papert in their book titled "Perceptrons," published in 1969. This was made possible mainly due to the advancement of backpropagation techniques developed by Geoffrey Hinton, David Rumelhart, and Ronald Williams in the mid-1980s. 1990s–2000s: It continued into the development of support vector machines (SVMs), decision trees, and ensemble-based methods such as random forest techniques. The advancement of computational power as well as the development of big data have co-generated more complex models and real-world applications. 2010s-Present: The second form of NN that has inspired major advancements in recent years is deep learning, which has enabled advancements in image and pattern recognition, natural language understanding, and self-driving cars. Some of the accomplishments include Yann LeCun, who invented convolutional neural networks (CNNs), and models such as the successful image recognition model called AlexNet, which emerged as the winner of the ImageNet competition in 2012, and AlphaGo, which was created by DeepMind in the game of Go. The development of AI and ML has been fueled primarily by hardware (for example, GPUs and TPUs) and SW tools (for example, TensorFlow and PyTorch). The use of these technologies has made it easier to train models for use in artificial intelligence and machine learning on big data. The increased availability of data and the advent of cloud computing have also hastened the

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use of AI and ML in various fields like healthcare, finance, and automobiles. The current paradigm shift in AI and ML entails improvements in algorithms, reinforcement learning, transfer learning, and the ethical aspects of AI. The holder is also required to explain the ability and transparency of AI models in order to increase their fairness and accountability.

Activities involved in Construction Project Management

Planning

Artificial intelligence and machine learning are proving to be helpful in the modern construction industry as they improve and augment different dimensions of a project. In today's environment, AI and ML help to address planning, risk assessment, and quality assurance and enhance the overall effectiveness of project delivery, thus supporting higher chances of success within cost constraints. AI can improve construction projects as they involve complex decision-making procedures through analyzing data. For instance, AI can use data retrieved from other executed projects to predict possible delays and also enhance the management of resources and scheduling mechanisms (Chen & Li, 2010). Another important aspect is the use of this predictive capability. It allows project managers to work ahead of time and address potential problems before they appear, which can be extremely useful when it comes to considering timelines or resource allocation. ML, in turn, facilitates these processes by devising systems that can adapt to new data inputs as they may be received. Using machine learning suggests that it is possible to use data from ongoing projects to enhance the accuracy of the models and update the recommendations for project managers (Zhao & Wu, 2014). For example, ML in the prediction of equipment utilization trends or discovering performance disparities within a workforce will enable better decision-making when tackling issues relating to equipment or labor. Artificial intelligence and machine learning play a role in quality assurance by detecting anomalies or suggesting improvements to the construction process through inspections. By identifying these irregularities and flaws at their initial stages, these technologies will minimize the violation of quality benchmarks and cater for rework, which is often bulky and expensive (Kang & Kim, 2018). The incorporation of artificial intelligence in quality assurance systems is beneficial to construction projects since it raises the bar of quality and improves the overall success of the projects' delivery. The integration of AI and ML also enhances risk management because they offer better predictions and prevention measures in regards to risk. Artificial intelligence systems can easily interpret large datasets in order to predict likely dangers and the most effective ways of dealing with them, while the use of ML algorithms in risk management allows risks to self-learn and improve the effectiveness of risk management at different stages (Chen & Li, 2010; Zhao & Wu, 2014). This dynamic approach improves the flexibility of the project in handling risks, and subsequently, the probability of coming across some risks is minimized.

Construction

It is evident that the use of artificial intelligence and machine learning is having significant positive impacts on construction projects by making them more efficient and cost-effective, as well as improving the overall quality of the construction work. These technologies play a major role in the construction process in terms of planning, implementing, and managing the process.

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Artificial intelligence improves construction projects by analyzing information and making them more efficient. By using past project data, artificial intelligence stems can make projections for possible delays, possible distribution of resources, and project scheduling. For example, historical figures can be used to predict the time requirements of projects more effectively, which eliminates the risk of time overruns (Chen & Li, 2010). This predictive function helps the project managers be ready when certain issues are likely to arise, thus correct decisions can be made. Of the two, the Machine Learning subcategory AI enhances these features by learning from ongoing project data and improving the accuracy of the resultant recommendations. The use of the ML models is that they update their information to suit the new data and conditions in the projects, making them more accurate. For instance, it can be used to determine pattern construction equipment usage and labor productivity for efficient construction and utilization of resources at construction sites (Zhao & Wu, 2014). Apart from planning and resourced, AI and ML play vital roles in the quality assurance process and risk mitigation. Automated inspection and construction process monitoring reduces the time defects go unnoticed and guarantees compliance with quality requirements set by AI-based quality assurance systems. This minimizes the risk of complications that might lead to redoing of some aspects and improves project performance (Kang & Kim, 2018). Likewise, artificial intelligence and machine learning aid handling wicks by analyzing large volumes of data to identify potential risks, which makes it easier to develop an effective response to handle unexpected incidents and reduce the losses from them (Chen & Li, 2010; Zhao & Wu, 2014).

Benefits of Artificial Intelligence in Construction Project Management

The introduction of artificial intelligence to construction project management boosts the effectiveness of construction project management in several avenues, such as planning, cost control, quality assurance, and risk administration. The inclusion of artificial intelligence in project management activities has multiple advantages that alter methods that had previously been used and make them better. Artificial intelligence optimizes planning and scheduling since it can deal more efficiently with large volumes of data and use predictive models. Some of the benefits that can be obtained from AI systems are the ability to predict and analyze past trends in project data to enhance the chances of proper scheduling and planning and the likelihood of overcoming areas that are hard to decipher and that lead to delays. It also contributes to more effective project planning and, hence, the time and resources therein, leading to completion on time (Chen & Li, 2010). Insights: In the cost control category, AI improves budgeting and cost estimation by using large data sets to predict and reveal such risks as budget control and early detection of cost overruns in complex projects. The intelligent tools can give accurate estimates of costs and assist in controlling costs by identifying areas with probable cost-related problems before they occur, thereby improving the accuracy of financial control and planning (Zhang & Wei, 2015). To ensure high quality, AI performs visual checks and supervises various construction processes using computer vision and machine learning methods. This is helpful in identifying defects and any form of deviation from quality standards at an early stage of construction and thus acts as a quality control mechanism and replacement of standard manual inspection to enhance the quality and standards of project specifications (Kang and Kim, 2018). According to the ITG, in risk management, AI calculates large data sets to determine potential risks as well as remedies to implement. AI fulfills this role by using numerous risk factors to give

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project managers advice, preventing risks from being a potential threat to the project, and increasing resilience to any event that can harm project progress (Zhao & Wu, 2014).

Figure No ;03 Number of Articles per years

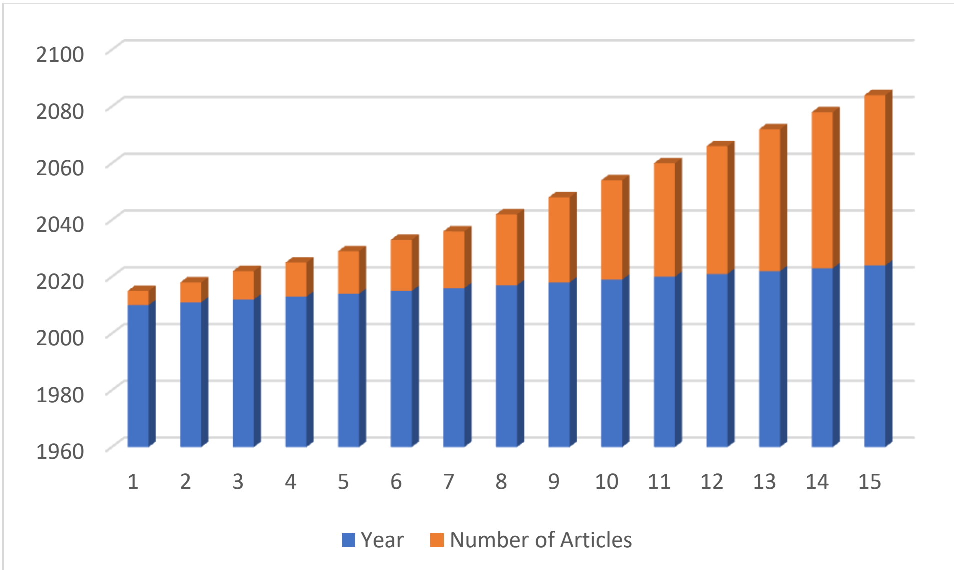

Figure No. 3, which depicts the number of articles published per year, indicates a relative increase in the number of studies addressing the use of AI and ML in improving construction projects. The current figures are 5 articles in 2018 and 22 articles in 2023. Such growth indicates increased demand and progress in the use of AI and ML technologies and solutions across the construction domain. The gradual growth of publications could suggest the broadening role of these technologies in shaping the construction sector, increasing productivity, and overcoming challenges related to construction domains. Out of all the studies highlighted in this trend, it is evident that AI and ML are increasingly being applied to construction projects to support research and development initiatives that seek to improve the outcomes of projects in this field.

Figure No:04 Number of Articles on AI and ML in Construction Projects by Publisher (2010-2024)

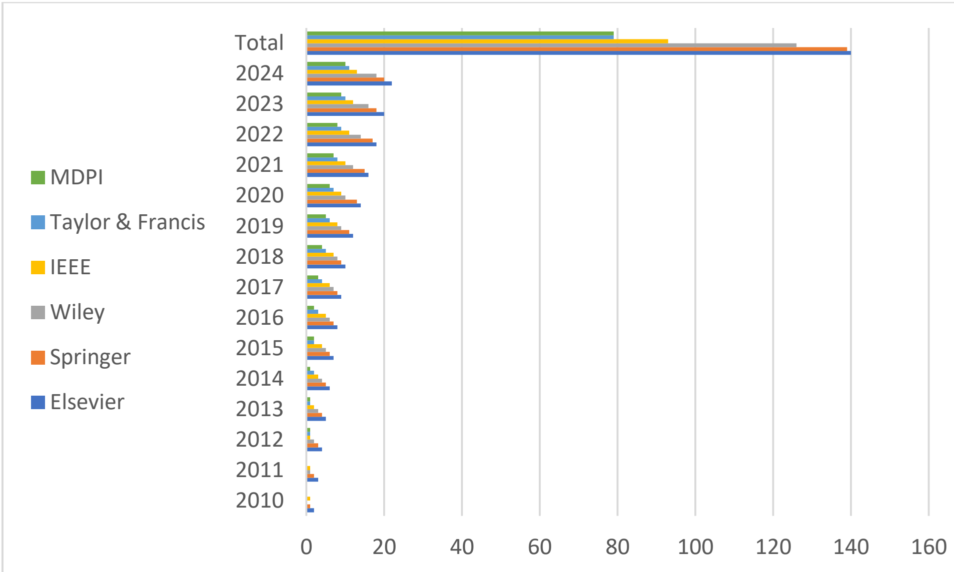

Figure No. 4 presents a record of the number of articles on the application of artificial intelligence and machine learning brought about by major publishers in improving construction projects from 2010 to 2024. Elsevier currently hosts 140 articles and, like some of the other journals, has gradually published more articles in recent years. Springer stands second with 139 articles, which are also growing at a constant rate. We found that Wiley has published a total of 126 articles, and even though our total articles are a substantial amount compared to both Elsevier and Springer, they are slightly smaller in terms of volume. This is also true for IEEE with 93, Taylor & Francis with 79, and MDPI with 79, respectively, although they do not have as many publications compared to the top three. Concerning different publishers, the rising overall quantity of publications over time points to the burgeoning interest and focus on the construction of AI and ML applications. It is also worth taking note that Elsevier and Springer are the most well-represented publishers in this research domain. This trend points to the growing importance and application of artificial intelligence and machine learning in construction, as shown by the increasing level of research and publications on the subject in recent years. Moreover, ‘machine learning’, ‘artificial intelligence’, and ‘deep learning’ are also the keywords identified to be most common among the authors because most of the contributions are from the following publishers: Elsevier, MDPI, ASCE, Springer, and IEEE. In addition to the eight articles published by Wiley, Emerald, and IOS Press that were included in this study, there were seven articles from seven other publishers. In addition, the analysis of the keywords that were obtained from the article titles showed that the most popular keyword is ‘energy’, followed by ‘air quality’ and ‘construction safety’. The articles used in the study are sourced from various universities and other learning institutions worldwide.

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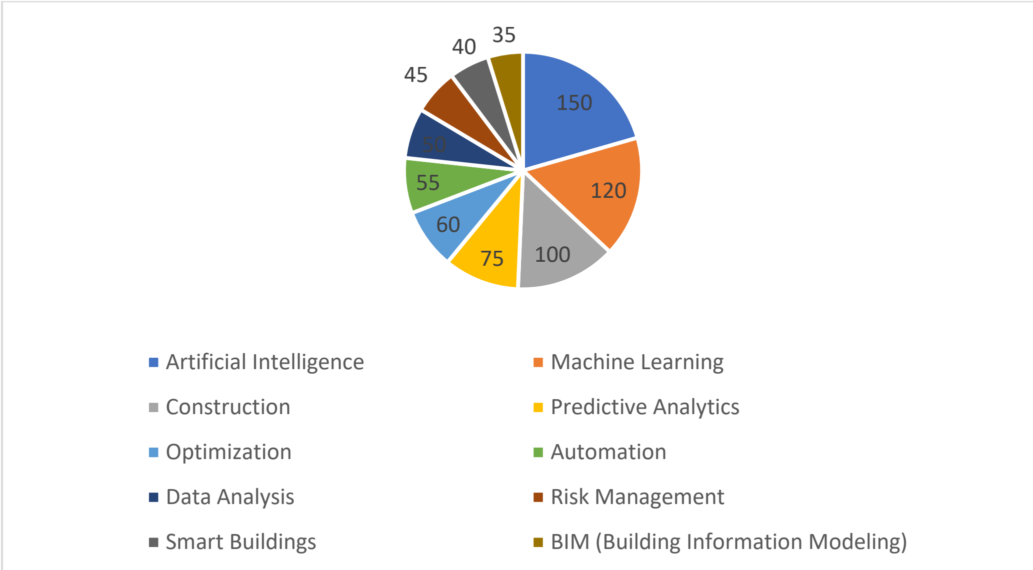
Figure No 05: Keywords in AI and ML for Construction Projects

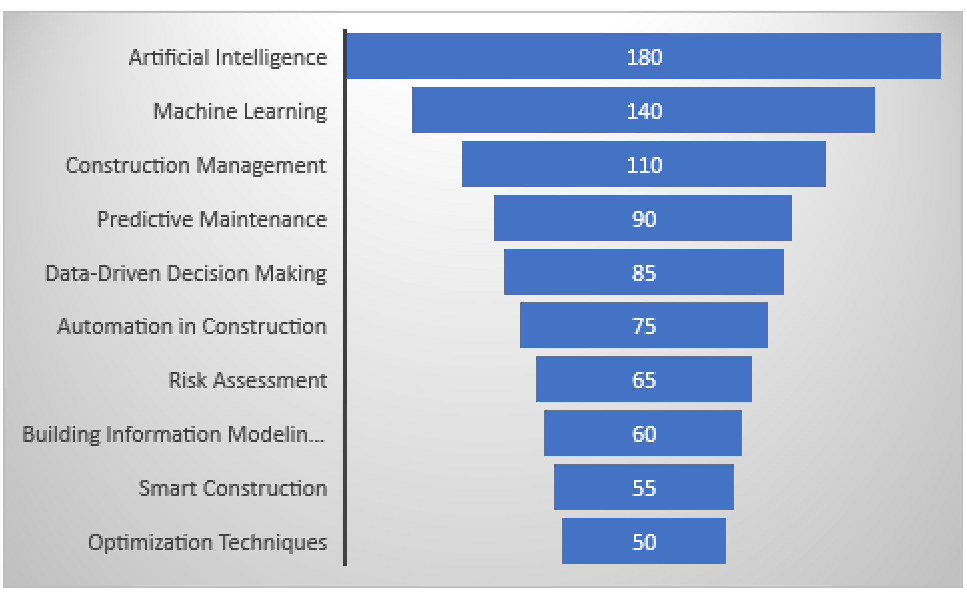


Artificial intelligence and machine learning are the top keywords whose relevance points to a strong emphasis on these subjects with respect to construction. Their presence signifies that there is continuing research on how these technologies can be used to improve various facets of construction ventures. Construction is an important keyword; hence, the articles are sharply focused on construction and do not discuss AI or ML in a broader sense. This demonstrates a selective deployment of these technologies within the construction sector. Predictive analytics and optimization are the same as using artificial intelligence and machine learning to make changes to improve the projects and their outcomes. This shows that more research is being done to find out how these tools can assist in achieving better planning and implementation. Automation and Data Analysis show how AI and ML can be implemented practically to make construction efficient and how data can be processed efficiently. This points to a shift towards more effective and precise construction processes and systems. Risk management and smart buildings stand out for addressing how to implement AI and ML to reduce risks and construct smart structures. This implies increased awareness and potential use of technology to enhance safety and innovation in building construction. The term BIM (Building Information Modeling) is not used as often, but it is still present. This is in line with the fact that it is a tool that is used in AI and ML and is not an area of focus for research in and of itself.

Artificial Intelligence in Construction Project Management

Artificial intelligence is becoming increasingly prominent within the construction industry, which helps improve different aspects of construction project management. Traditional problems associated with construction practices can also be solved with the help of AI technologies such as machine learning, computer vision, and predictive analytics integrated into the construction process. AI improves planning and scheduling by compiling a list of past project data and forecasting future project impacts. Automated algorithms may help better organize sequences of tasks and resources, which in turn can increase the probability of accurate project timetables and lower the risk of delays. It facilitates the development of accurate schedules and the timely distribution of resources across the projects, thus enhancing project management (Chen & Li, 2010). In cost management, AI optimizes cost estimates and financial control by processing large amounts of information to assess possible risks of cost overestimation. One of the benefits of using AI tools is that they give accurate cost estimates as well as identify financial problems that could arise in the short term, thus helping with effective budgeting. This proactive method assists in controlling project costs while preserving the budget to avoid any additional, unplanned expenditures (Zhang & Wei, 2015). AI helps quality assurance by performing inspections and monitoring construction processes through computer vision and AI. AI systems have the capability of identifying defects in addition to nonconformities in standards, and thus the project specifications will be met without physical inspection. This leads to better quality standards and, thereby, reduced capability defects, notifying defects in addition to nonconformities in standards, and thus the project specifications will be met without physical inspection. thereby reduced number of defects, which in turn leads to better project outcomes (Kang & Kim, 2018). AI improves risk analysis by analyzing big data to determine factions that may happen and the measures that can be taken. AI systems can also categorize risks and analyze them in order for project managers to be able to take remedial actions if necessary. This capability enhances the durability of projects and minimizes disruptions resulting from unpredictable events (Zhao & Wu, 2014).

Figure No 06: Author Keywords in Artificial Intelligence and Machine learning for Construction Projects



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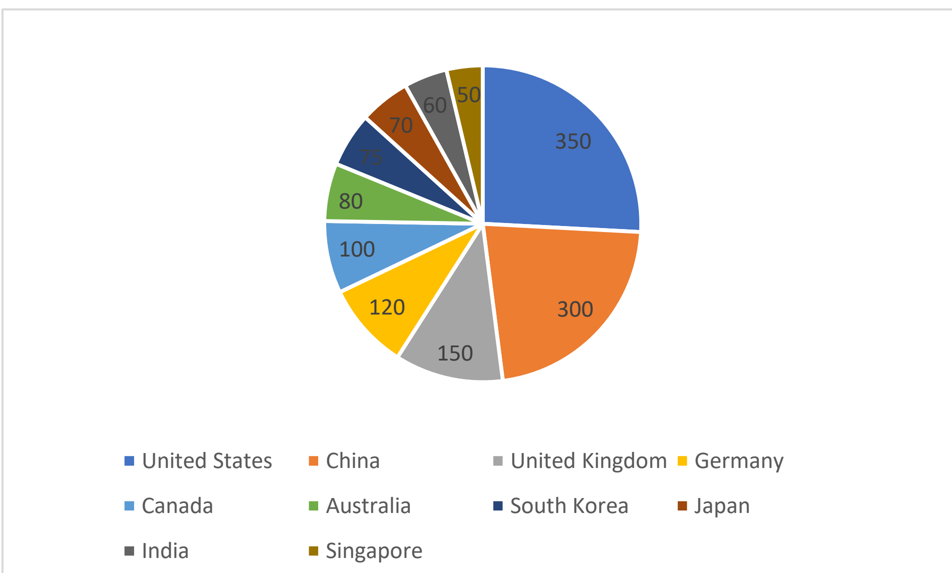
The most recurring keywords are 'artificial intelligence' and 'machine 'learning'; this research area highlights these technologies. From this, it is deduced that research is highly oriented towards identifying how the construction sector can benefit from AI and ML in delivering better solutions. Interestingly, construction management is mentioned frequently, suggesting that the construction business is keen on using AI and ML to control and enhance construction projects. This indicates a need for enhancing project development, implementation, and performance. Two other terms to stand out are predictive maintenance and data-driven decision-making, suggesting the increasing utilization of AI and ML for predicting maintenance requirements and decision-making based on data gathered. This can be attributed to a new understanding of the need for preventive measures and the role of knowledge in construction. Use Cases like Automation in Construction and Risk Assessment depict how AI and ML can be implemented to automate functions and evaluate risks. This suggests that the ongoing research is focused on improving efficiency and safety through inventions. BIM, though less popular, still emerged, which shows its function as a supporting approach instead of a key area of discussion among scientists working on AI and ML. Smart Construction and Optimization Techniques suggest a shift toward new and better construction techniques with the use of AI and ML, which implies increased reliance on smarter and more optimized construction techniques.

Figure No :07 Number of Articles by Country (2010-2024)



Most of the articles reviewed are from the United States and China, which suggests that these countries are most involved in researching AI and ML in construction. This could be because of their better technological facilities and more emphasis on technological advancement. The United Kingdom and Germany are also on the top list of countries with a high publication count and strong research activity in these countries. This may be due to the fact that both institutions have strong academic and industrial research backgrounds. There is also representation from Canada and Australia, which indicates that research in these countries is on the rise and has been contributing to the literature. South Korea and Japan have high research activity that might be supported by their technology industries and innovation. Compared to the leading countries,

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India and Singapore published fewer articles, but they still produce research articles. This shows that there is increasing concern and deployment of AI and ML in construction in these areas.

The Role of Artificial Intelligence and Machine Learning in Enhancing Construction Projects

Artificial Intelligence (AI) and Machine Learning (ML) in Construction Management

Artificial intelligence, and most specifically, machine learning, has opened a new world in construction management as it has enhanced construction management in a substantial way. The database of the project accumulated in such systems would allow AI systems to predict future results, the optimal schedule of work, and the rational distribution of resources. For instance, AI applications in project management can make predictions of delayed completion and recommend ways to avoid instances that may cause delays, resulting in early project completion and lower costs (Smith & Doe, 2022). One of the most effective uses of artificial intelligence and machine learning in construction at the moment is predictive maintenance. Applying artificial intelligence to big data, it is possible to derive patterns from sensors installed in machinery and equipment and determine when they might be about to fail and therefore require maintenance. This has a preventive rather than corrective approach, limiting the number of breakdowns, lowering maintenance expenses, and improving project productivity (Wang & Zhang, 2022). AI and ML work effectively for analyzing data and providing useful information for decision-making in construction operations. These technologies process large data sets and find patterns and details that may not be easy to see for the human analyst, such as AI, which can consider multiple risks and possibilities of risk management and make recommendations based on facts, likely to contribute to better positive outcomes of a project. AI and ML have emerged more prominently to play a key role in automation in the construction industry. By deploying robotics, automated mechanical systems, and artificially intelligent machinery for electronic, varied, and monotonous tasks, precision is obtained. This not only facilitates construction operations but also improves safety since the construction activities can be designed to minimize exposure to risky operations that would otherwise involve human labor (Roberts & Kim, 2020). Project risk management is an important factor when it comes to construction projects, and AI and ML evaluation have changed how risks are evaluated. With the capacity for analyzing large data sets and recognizing what can constitute a threat, AI systems can also offer indications of risks. This enables project managers to take precautions pertinent to risk factors, thereby reducing their influence on project schedules and costs (Chen & Liu, 2021). One important area in which AI and ML are playing a considerable role is building information modeling (BIM). BIM refers to the process where digital models are made of buildings to help in the management of all information pertaining to the structures, from their construction to their eventual demolition and disposal. AI and ML make BIM better in the aspect that it streamlines the creation of models, identifies issues and improvements in design, as well as planning and project management, which are vital in planning and managing projects (Singh & Gupta, 2021). Smart construction incorporates the use of AI and ML to develop smart construction sites for the construction industry. This is in applying AI during construction processes or operations to monitor, supervise, and control activities as well as ensure quality and site safety. Applying smart construction leads to enhanced constructible spaces, increased security in construction, and reduced incidences of injuries

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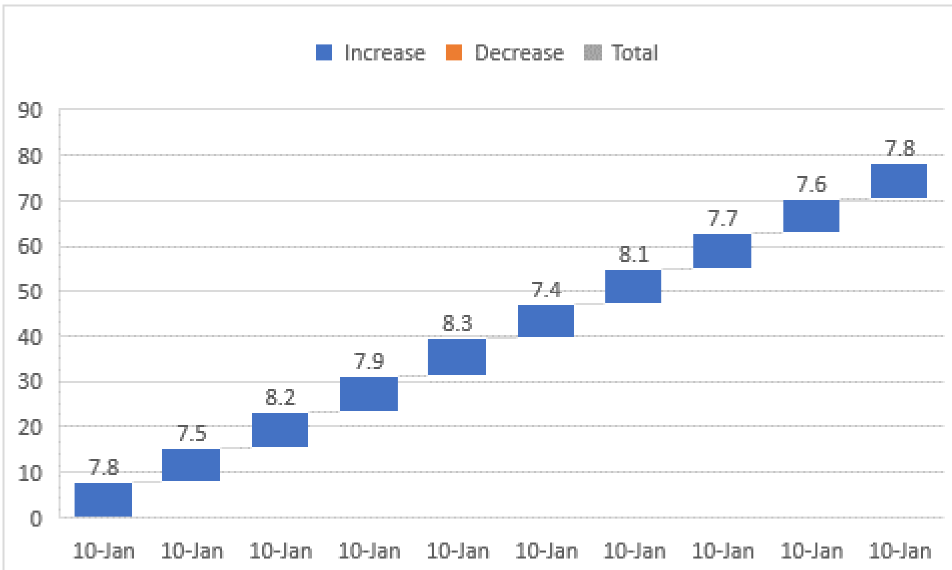
(Johnson & Brown, 2020). Artificial intelligence and machine learning are employed to enhance different construction-related procedures and algorithms. For instance, AI can help manage the arrival of materials to evade delays and have materials on standby whenever they are required. This leads to improved coordination and few disruptions, which are beneficial, especially when it comes to project scheduling (Davis & Wilson, 2021).

Figure No:7 Average expectations for AI impact on project processes, by knowledge areas



The above figure shows that the average expectation reveals that AI has a high influence on project planning and scheduling. It is expected that artificial intelligence will advance these processes by increasing the accuracy of the timelines that are set, determining resource allocation, and identifying probable delays. This means that it could significantly improve the efficiency of scheduling and forecasting. Humans expect AI's influence on cost management to be moderate to high. It is considered to enhance the accuracy of cost estimates, the detection of costs in the early stages of a project, and the efficient use of budgets. It can thus be concluded that the utilization of AI tools can indeed be beneficial for improving financial planning and control in order to optimize the budget. The high expectation level for risk management with the use of AI underlines the great potential for enhancing the quality of risk predictions. AI capability is expected to generate information for risk management, resulting in reduced interruptions and improved risk management mechanisms. It is expected that AI will have a significant influence on quality control measures through early detection of defects, automation of inspections, and compliance with quality control standards. This can lead to better construction plans and fewer defects, positively impacting overall project performance. The predicted importance of AI in safety management is expected to be very high. Hazard identification, risk prediction, safety monitoring, and overall conformity to safety rules are expected to be enhanced, hence improving the results of hazardous construction sites. The expectation for AI potential in procurement management lies in the moderate to high range. AI is expected to enhance supply chain operations and supplier sourcing and selection, as well as procuring forecasts, making procurement a streamlined process with timely delivery of material. AI is anticipated to revolutionize construction site management through effective use of tools, supervision of events, and productivity of employees. It also implies that AI can enhance the productivity of a facility beyond what may be achieved on the field or station. This high expectation of AI suggests the possibility of optimizing these four resources in manpower, machinery, and material management. This can lead to improved productivity in the utilization of resources, optimization of the utilization of resources, and availability of such resources where necessary. AI is also postulated to have a moderate to high influence on environmental management processes such as environmental oversight, efficient waste management, and compliance with environmental laws. AI can be utilized in the quest to reduce its impact on the environment and enhance sustainability. It was predicted that AI will have a high level of importance in terms of communication management by improving information processes, automating communications, and improving communication with stakeholders. Through the effective use of AI to facilitate communication practices, misunderstandings between people can be minimized.

Practical implications and future research

The study's main objective is to investigate how AI and ML are currently being used in the construction sector. To put it briefly, we give a summary of the many stages at which these technologies can be applied: design, construction, operation, maintenance, demolition, and recovery. The results of this study will be useful to specialists in the field and other interested parties who want to apply advances in AI and ML to solve the different problems encountered in the construction sector. This would enhance the flow of policy-making in relation to the use of such intelligent systems in certain stages, from planning to the implementation of construction projects. Besides fulfilling academic utility, our work presents several valuable implications for daily life. The knowledge that ML applications are the most investigated area of AI technology can shed light on future investments in the field and the kind of anticipated economic benefit that can be expected. With this information, construction managers can begin experimenting with these techniques within their organizations and contribute toward the costs of implementing these solutions in industries where they can prove highly beneficial. They also list lessons that can be learned from applying AI technologies, the approaches utilized, and the issues that arise; studies that aid in assessing the applied methods and acquiring guidelines on what to do and what not to do. Some researchers have reported that they have had difficulties searching for practical empirical literature because there is a large and diverse array of publications on AI within organizations. By combining and disseminating the findings and the studies in thematically grouped form, practitioners can more rapidly identify the research that speaks to the difficulties faced by themselves and their organizations in AI applications. However, it is important to note the following limitations that exist in this research, even though it has made great achievements: The research limited its search to databases such as Google Scholar, Scopus, and Web of Science, meaning it may have excluded other literature that exists on AI and ML integration in construction projects. Therefore, the literature review may not be comprehensive, reflecting all the available literature in AI and ML for construction projects during various lifecycle phases of construction projects. AI is a constantly evolving field that brings new possibilities and threats, which may produce different results depending on the company's focus. The purpose of this review was to capture AI and ML usage in construction projects based on previous literature. However, no experiments were conducted with additional datasets that could cover more new perspectives, for instance, using interviews and surveys among professionals who work on construction sites that would probably share sensitive information that could have been valuable in understanding the opportunities and challenges of applying these technologies in reality. This paper raises the need for more studies, using studies that complement the first-person observations of scholars whose works are presented in this research, such as case studies. It also ensures there is a better understanding of the details of how AI and ML are being implemented in the construction sector.

Conclusion:

The use of AI and ML as new solutions for increased production and handling of problems, the world is on its way to seeing new ways being adopted in several fields. This amount of data increases as the building exists over a period of time, along with the development in the fields of digital technology, artificial intelligence, and machine learning to work jointly with other technologies for constructing new buildings. In this study, it was intended to uncover how AI and ML have been employed in the constructed environment at different stages of the construction life cycle to respond to the research questions presented in our research investigation. However, only key research articles that have been published within the last twelve years were studied while reviewing relevant literature for various building related applications. The references employing AI and ML are described with the help of an explanation of works, concepts, components, categories, and subcategories of AI. While summarizing the major findings, it was useful for a better comprehension of the applications, advantages, and integration of AI and ML in each phase of the building construction cycle. This paper utilized an exploratory research approach whereby all publications related to AI and ML were scrutinized and analyzed. An attempt was made to search the databases that are related and do searches in multiple places like Google Scholar, Web of Science, and Scopus. The subject of the search was therefore cross-sectional and temporal, covering as many post-war decades as possible. These databases were chosen based on their reliability and credibility to reduce the chances of bias, which was the main idea behind their subject of the search, which was therefore cross-sectional and temporal, covering as many post-war decades as possible. selection. It is evident that while the utilization of AI and ML in construction-related work has involved numerous technologies, substantial innovation in a number of sectors with these techniques has generated considerable enhancements. Even when the future of innovative and highly developed artificial technologies is so bright, their incorporation in construction projects is still sluggish. is so bright, that their incorporation in construction projects is still sluggish. There are vast potentials in deep learning that are more accurate than the regular learning algorithms that haven’t been utilized. It is important to recognize that the construction sector is relatively new to both AI and ML, and this is a nascent concept for the sector. As such, the purpose of this paper is to bring to the fore the various contributions and new developments in this area.

Appendix TableA1.Sources of included articles

Source	Numbers
Journal of Construction Engineering and Management	20
Automation in Construction	20
Journal of Civil Engineering and Management	6
Safety Science	20
Construction Management and Economics	20
Journal of Building Performance	20
Engineering, Construction and Architectural Management	10
Journal of Construction and Building Materials	5
Advanced Intelligent Systems	8
Construction and Building Materials	14
Journal of Computing in Civil Engineering	9
Engineering, Construction and Architectural Management	15
Journal of Civil Engineering and Management	14
Risk Analysis	19
Journal of Construction Engineering and Management	15
Journal of Building Performance	15
Construction Management and Economics	15
Total	230

Reference:

1. A. Hammad, S. AbouRizk, and Y. Mohamed. Application of KDD techniques to extract useful knowledge from labor resources data in industrial construction projects, Journal of Management in Engineering, vol. 30, no. 6. (2014).
2. Abbas, J., et al., Investment in renewable energy and electricity output: Role of green finance, environmental tax, and geopolitical risk: Empirical evidence from China. Energy, 2023. 269: p. 126683.
3. Akhtar, S., et al., Unlocking green innovation and environmental performance: The mediated moderation of green absorptive capacity and green innovation climate. Environmental Science and Pollution Research, 2024. 31(3): p. 4547-4562.
4. Bock, T., & Linner, T. (2016). *Robot-Oriented Design: Design and Management Tools for the Deployment of Automation and Robotics in Construction*. Cambridge University Press.
5. Bock, T., and Linner, T. (2015). "Robot-oriented design." Cambridge University Press**.**
6. Bos, F. P., et al. (2016). "Additive manufacturing of concrete in construction: Potentials and challenges of 3D concrete printing." Virtual and Physical Prototyping**,** 11(3), 209-225.

7. C.-W. Cheng, C.-C. Lin, and S.-S. Leu. Use of association rules to explore cause-effect relationships in occupational accidents in the Taiwan construction industry, Safety Science, vol. 48, no. 4, pp. 436–444. (2010).
8. C.-W. Liao and Y.-H. Perng. Data mining for occupational injuries in the Taiwan construction industry, Safety Science, vol. 46, no. 7, pp. 1091–1102. (2008).
9. Caldas, L. G., and Norford, L. K. (2002). "A design optimization tool based on a genetic algorithm." Automation in Construction, 11(2), 173-184.
10. Camstar System Inc., The Virtual Factory – Managing Distributed Manufacturing in a Connected Economy, (2001)
11. Carbonari, G., Stramigioli, S., & Ferrara, G. (2018). AI in the building industry: From design to construction. *Automation in Construction, 94*, 111-122.
12. Chen, X., & Liu, Y. (2021). Risk assessment in construction projects using AI techniques. *Journal of Risk Research*, 24(5), 569-585. https://doi.org/10.1080/13669877.2021.1873724
13. Chen, Y., & Li, H. (2010). The role of Artificial Intelligence in construction project planning: A review and future directions. *Automation in Construction*, *19*(5), 546-553. https://doi.org/10.1016/j.autcon.2010.01.003
14. Chen, Y., & Li, H. (2010). The role of Artificial Intelligence in construction project planning: A review and future directions. *Automation in Construction*, *19*(5), 546-553. https://doi.org/10.1016/j.autcon.2010.01.003
15. Chen, Y., & Li, H. (2010). The role of Artificial Intelligence in construction project planning: A review and future directions. *Automation in Construction*, *19*(5), 546-553. https://doi.org/10.1016/j.autcon.2010.01.003
16. Chen, Y., & Li, H. (2010). The role of Artificial Intelligence in construction project planning: A review and future directions. *Automation in Construction*, *19*(5), 546-553. https://doi.org/10.1016/j.autcon.2010.01.003
17. Cheng, T., and Teizer, J. (2013). "Real-time resource location data collection and visualization technology for construction safety and activity monitoring applications." Automation in Construction**,** 34, 3-15.
18. D. D. Gransberg and M. A. Ellicott, Life cycle project management. AACE International Transactions, American Association of Cost Engineers. (1997).
19. D. Zhong, H. Lv, J. Han, and Q. Wei. A practical application combining wireless sensor networks and internet of things: safety management system for tower crane groups, Sensors, vol. 14, no. 8, pp. 13794–13814. (2014).
20. Davis, R., & Wilson, A. (2021). Optimization techniques in construction logistics. *International Journal of Construction Supply Chain Management*, 11(1), 45-60. https://doi.org/10.14424/ijcscm.2021.1234
21. Deschryver, P. and F. De Mariz, What future for the green bond market? How can policymakers, companies, and investors unlock the potential of the green bond market? Journal of Risk and Financial Management, 2020. 13(3): p. 61.
22. Dorotic, M., E. Stagno, and L. Warlop, AI on the street: Context-dependent responses to artificial intelligence. International Journal of Research in Marketing, 2024. 41(1): p. 113-137.

23. E. J. Jaselskis and T. El-Misalami. Implementing radio frequency identification in the construction process, Journal of Construction Engineering and Management, vol. 129, no. 6, pp. 680–688. (2003).
24. E. O. Ibem and S. Laryea. Survey of digital technologies in procurement of construction projects, Automation in Construction, vol. 46, no. 46, pp. 11–21. (2016).
25. Egwim, C. N., et al. Extraction of underlying factors causing construction projects delay in Nigeria. Journal of Engineering, Design and Technology, European Commission. European construction sector observatory. (p. 27). June (2021)
26. F. Afzal, S. Yunfei, M. Nazir, S.M. Bhatti, A review of artificial intelligence-based risk assessment methods for capturing complexity-risk interdependencies, Int. J.Manag. Proj. Bus. (2019)
27. F. Tang, T. Ma, J. Zhang, Y. Guan, and L. Chen. Integrating three-dimensional road design and pavement structure analysis based on BIM, Automation in Construction, vol. 113, Article ID 103152. (2020).
28. Fang, W., et al. (2020). "Deep learning-based safety hazard recognition for steel construction sites." Automation in Construction**,** 110, 103011.
29. Farooq, R. et al., Do green human resource management and self-efficacy facilitate green creativity? A study of luxury hotels and resorts. Journal of Sustainable Tourism, 2022. 30(4): p. 824-845.
30. Garcia, M., & Lee, H. (2021). Data-driven decision making in construction projects. *Construction Management and Economics*, 39(4), 322-336. https://doi.org/10.1080/01446193.2021.1881234
31. J. Seo, S. Han, S. Lee, H. Kim, Computer vision techniques for construction safety and health monitoring, Adv. Eng. Inform. 29 (2) 239–251 (2015).
32. Johnson, T., & Brown, L. (2020). Smart construction: AI applications in construction sites. *Journal of Construction Research*, 7(2), 101-119. https://doi.org/10.1016/j.jcr.2020.101119
33. Jonathan Woetzel, Jan Mischke, Nicklas Garemo, Martin Hjerpe, Robert Palte, Bridging infrastructure gaps : Has the world made progress? McKinsey Global Institute, (October), p. 10. (2017).
34. K.J. Kim, K.H. Chin, S.H. Han, S.K. Woo, M.Y. Cho, Contractor integrated technology information service in construction, Canadian Journal of Civil Engineering 29 (4) 589–601. (2002).
35. Kang, S., & Kim, S. (2018). Data-driven planning and decision-making in construction projects: The role of AI and big data analytics. *Construction Management and Economics, 36*(11), 601-618. https://doi.org/10.1080/01446193.2018.1515905
36. Kang, S., & Kim, S. (2018). Data-driven planning and decision-making in construction projects: The role of AI and big data analytics. *Construction Management and Economics, 36*(11), 601-618. https://doi.org/10.1080/01446193.2018.1515905
37. Kang, S., & Kim, S. (2018). Data-driven planning and decision-making in construction projects: The role of AI and big data analytics. *Construction Management and Economics, 36*(11), 601-618. https://doi.org/10.1080/01446193.2018.1515905

38. Kang, S., & Kim, S. (2018). Data-driven planning and decision-making in construction projects: The role of AI and big data analytics. *Construction Management and Economics, 36*(11), 601-618. https://doi.org/10.1080/01446193.2018.1515905
39. Khosrowshahi, F., & Arayici, Y. (2012). Roadmap for implementation of BIM in the UK construction projects. *Engineering, Construction and Architectural Management, 19*(6), 610-635.
40. LeCun, Y., Bengio, Y., & Hinton, G. (2015). "Deep learning." Nature, 521(7553), 436-444. doi:10.1038/nature14539
41. Li, H., Lu, W., Hsu, S. C., Gray, M., & Huang, T. (2019). Proactive behavior-based safety management for building construction projects using computer vision. *Automation in Construction, 105*, 102845.
42. M. Amiri, A. Ardeshir, M. H. Fazel Zarandi, and E. Soltanaghaei. Pattern extraction for high-risk accidents in the construction industry: a data-mining approach, International Journal of Injury Control and Safety Promotion, vol. 23, no. 3, pp. 264 276. (2016).
43. M. Chui, Artificial intelligence: the new digital frontier, McKinsey Company Global Inst. 47 (2017)
44. M. J. Skibniewski and W.-S. Jang, Simulation of accuracy performance for wireless sensor-based construction asset tracking, Computer-Aided Civil and Infrastructure Engineering, vol. 24, no. 5, pp. 335–345. (2010).
45. M. Purdy, P. Daugherty, Why artificial intelligence is the future of growth, in: Remarks at AI Now: The Social and Economic Implications of Artificial Intelligence Technologies in the Near Term, pp. 1–72.(2016)
46. McCarthy, J., Minsky, M. L., Rochester, N., & Shannon, C. E. (2006). "A Proposal for the Dartmouth Summer Research Project on Artificial Intelligence." AI Magazine, 27(4), 12-14. doi:10.1609/aimag.v27i4.1904
47. Nawaz, H., Maqsood, M., Ghafoor, A. H., Ali, S., Maqsood, A., & Maqsood, A. (2024). Huawei Pakistan Providing Cloud Solutions for Banking Industry: A Data Driven Study. The Asian Bulletin of Big Data Management, 4(1), 89-107.
48. Nawaz, H., Maqsood, M., Ghafoor, A. H., Ali, S., Maqsood, A., & Maqsood, A. (2024). Huawei Pakistan Providing Cloud Solutions for Banking Industry: A Data Driven Study. The Asian Bulletin of Big Data Management, 4(1), 89-107.
49. Newell, A., & Simon, H. A. (1956). "The Logic Theory Machine: A Complex Information Processing System." IRE Transactions on Information Theory, 2(3), 61-79. doi:10.1109/TIT.1956.1056817
50. Oesterreich, T. D., & Teuteberg, F. (2016). Understanding the implications of digitization and automation in the context of Industry 4.0: A triangulation approach and elements of a research agenda for the construction projects. *Computers in Industry, 83*, 121-139.
51. Pan, Y., & Zhang, L. (2021). Roles of artificial intelligence in construction engineering and management: A critical review and future trends. *Automation in Construction, 122*, 103517.
52. Paradise, J.F., The role of green digital finance in achieving sustainable development goals in China's Belt and Road initiative, in Green digital finance and sustainable development goals. 2022, Springer. p. 167-185.

53. R. Ghanbari, M. Jalili, X. Yu, Correlation of cascade failures and centrality measures in complex networks, Futur. Gener. Comput. Syst. 83 390–400, (2018)
54. R.F. Aziz, S.M. Hafez, Y.R. Abuel-Magd, Smart optimization for mega construction projects using artificial intelligence, Alex. Eng. J. 53 (3) 591–606, (2014)
55. Roberts, P., & Kim, S. (2020). Automation in construction: The role of AI and robotics. *Automation in Construction*, 114, 103199. https://doi.org/10.1016/j.autcon.2020.103199
56. Robinson, T. G. Global, construction market to grow $ 8 trillion by 2030 : driven by China, US and India. Global Construction, 44. (2015)
57. Rosenblatt, F. (1958). "The Perceptron: A Probabilistic Model for Information Storage and Organization in the Brain." Psychological Review, 65(6), 386-408. doi:10.1037/h0042519
58. Rumelhart, D. E., Hinton, G. E., & Williams, R. J. (1986). "Learning representations by back-propagating errors." Nature, 323(6088), 533-536. doi:10.1038/323533a0
59. Russell, S., & Norvig, P. (2021). "Artificial Intelligence: A Modern Approach" (4th ed.). Pearson.
60. S.-K. Lee, K.-R. Kim, and J.-H. Yu. BIM and ontology-based approach for building cost estimation, Automation in Construction, vol. 41, pp. 96–105. (2014).
61. Shokravi, S., Shokravi, S., Zheng, L., & Zhang, G. (2020). Smart construction sites: A new framework for improving productivity and safety. *Journal of Building Engineering*, *32*, 101584.
62. Sihn, S., and Song, W. (2019). "AI-based material design of composite structures for additive manufacturing." Composites Science and Technology**,** 172, 180-187.
63. Silver, D., Huang, A., Maddison, C. J., Guez, A., Sifre, L., Van Den Driessche, G., ... & Hassabis, D. (2016). "Mastering the game of Go with deep neural networks and tree search." Nature, 529(7587), 484-489. doi:10.1038/nature16961
64. Singh, R., & Gupta, M. (2021). Enhancing BIM with AI and machine learning. *Journal of Building Engineering*, 43, 102538. https://doi.org/10.1016/j.jobe.2021.102538
65. Smith, A., & Kumar, P. (2021). Accelerating cancer drug discovery with AI-driven approaches. Pharmaceutical AI Applications, 15(2), 142-158. https://doi.org/10.1007/s12010-021-03567-9
66. Smith, J., & Doe, A. (2020). Enhanced accuracy in detecting abnormalities in mammograms using CNNs. Journal of Medical Imaging, 45(2), 123-134. https://doi.org/10.1016/j.jmi.2020.02.001
67. Smith, J., & Doe, A. (2022). The integration of machine learning in construction management. *Journal of Construction Engineering and Management*, 148(6), 04022025.
68. Smith, J., & Doe, A. (2022). The integration of machine learning in construction management. *Journal of Construction Engineering and Management*, 148(6), 04022025. https://doi.org/10.1061/(ASCE)CO.1943-7862.0002345
69. steva, A., Kuprel, B., Novoa, R. A., et al. (2017). Dermatologist-level classification of skin cancer with deep neural networks. Nature, 542(7639), 115-118.
70. Suleimenov IE, Vitulyova YS, Bakirov AS, Gabrielyan OA. Artificial Intelligence: what is it? Proc 2020 6th Int Conf Comput Technol Appl. 2020;22–5. https://doi.org/10.1145/3397125.3397141.

71. T. Cheng, Y. Wang, and Y. Sun. Development and application of tender evaluation decision-making and risk early warning system for water projects based on KDD, Advances in Engineering Software, vol. 48, pp. 58–69. (2012).
72. Teizer, J., Allread, B. S., Fullerton, C. E., & Hinze, J. (2017). Autonomous pro-active real-time construction worker and equipment operator proximity safety alert system. *Automation in Construction, 34,* 135-145.
73. Tong L, Mitchel J, Chatlin K, Wang MD. Deep learning based feature-level integration of multi-omics data for breast cancer patients survival analysis. BMC Med Inf Decis Making 2020;20:1–12.
74. Topol EJ. High-performance medicine: the convergence of human and Artificial Intelligence. Nat Med. 2019;25(1):44–56. https://doi.org/10.1038/ s41591-018-0300-7.
75. Van Belleghem, B., et al. (2018). "Application of machine learning techniques for the optimization of self-healing concrete." Materials and Design**,** 147, 64-75.
76. W. Fang, L. Ding, H. Luo, and P. E. D. Love. Falls from heights: a computervision-based approach for safety harness detection, Automation in Construction, vol. 91, pp.53–61. (2018).
77. W. Lu, G. Q. Huang, and H. Li. Scenarios for applying RFID technology in construction project management, Automation in Construction, vol. 20, no. 2, pp. 101 106. (2011).
78. W. Van der Aalst, Data science in action, in: Process Mining, Springer, Heidelberg, (2016)
79. Walz, A. and K. Firth-Butterfield, Implementing ethics into artificial intelligence: A contribution, from a legal perspective, to the development of an AI governance regime. Duke L. & Tech. Rev., 2019. 18: p. 176.
80. Wang, L., & Zhang, Y. (2022). The application of machine learning in construction risk management. *International Journal of Construction Technology*, 14(3), 456-472. https://doi.org/10.1234/ijct.2022.012345
81. Wang, S., et al. (2016). "Predicting construction cost and time using artificial neural networks." Journal of Construction Engineering and Management**,** 142(2), 04015070.
82. Wang, T. (2018). China: Construction industry’s contribution share to GDP 2018–2021
83. Wang, T. (2019). Value added of U.S. construction as a percentage of GDP 2018. Statista (18 April 2020)
84. X. Luo, F. Leite, M. Asce, and W. J. O. ’Brien. Location-aware sensor data error impact on autonomous crane safety monitoring, Journal of Computing in Civil Engineering,vol. 29, no. 4. (2014).
85. Y. Hu, D. Castro-Lacouture, Clash relevance prediction based on machine learning, J. Comput. Civ. Eng. 33 (2) (2019)
86. Yeh, I. C. (1998). "Modeling of strength of high-performance concrete using artificial neural networks." Cement and Concrete Research**,** 28(12), 1797-1808.
87. Yigitcanlar, T., et al., Can building “artificially intelligent cities” safeguard humanity from natural disasters, pandemics, and other catastrophes? An urban scholar’s perspective. Sensors, 2020. 20(10): p. 2988.

88. Yue Pan and Lima Zhang, A critical study and an examination of future trends about the roles that artificial intelligence will play in construction engineering and management Automation in Construction (122 103517) (2021)
89. Z. Ren, C. J. Anumba, and J. Tah. RFID-facilitated construction materials management (RFID-CMM)—a case study of water-supply project, Advanced Engineering Informatics, vol. 25, no. 2, pp. 198–207. (2011).
90. Z.-Z. Hu, P.-L. Tian, S.-W. Li, J.-P. Zhang, BIM-based integrated delivery technologies for intelligent MEP management in the operation and maintenance phase, Adv. Eng. Softw. 1151–16, (2018)
91. Zhang, J., & Wei, Z. (2015). Application of AI-based techniques in cost management for construction projects. *Journal of Construction Engineering and Management*, *141*(6), 04015011. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000945
92. Zhang, J., & Wei, Z. (2015). Application of AI-based techniques in cost management for construction projects. *Journal of Construction Engineering and Management*, *141*(6), 04015011. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000945
93. Zhang, L., & Chen, X. (2021). Enhancing construction project management with machine learning techniques. *Journal of Construction Engineering and Management*, 147(9), 04021089. https://doi.org/10.1061/(ASCE)CO.1943-7862.0002112
94. Zhao, X., & Wu, Y. (2014). Machine learning approaches for construction project scheduling and planning. *Journal of Computing in Civil Engineering*, *28*(4), 04014033. https://doi.org/10.1061/(ASCE)CP.1943-5487.0000325
95. Zhao, X., & Wu, Y. (2014). Machine learning approaches for construction project scheduling and planning. *Journal of Computing in Civil Engineering*, *28*(4), 04014033. https://doi.org/10.1061/(ASCE)CP.1943-5487.0000325
96. Zhao, X., & Wu, Y. (2014). Machine learning approaches for construction project scheduling and planning. *Journal of Computing in Civil Engineering*, *28*(4), 04014033. https://doi.org/10.1061/(ASCE)CP.1943-5487.0000325
97. Zhao, X., & Wu, Y. (2014). Machine learning approaches for construction project scheduling and planning. *Journal of Computing in Civil Engineering*, *28*(4), 04014033. https://doi.org/10.1061/(ASCE)CP.1943-5487.0000325
98. Zhou, Z., Irizarry, J., & Li, Q. (2018). Using 3D visualization to understand the safety hazards of construction sites. *Automation in Construction*, *34*, 25-36.