Original Article
ISSN (Online): 2350-0530
ISSN (Print): 2394-3629

International Journal of Research - GRANTHAALAYAH
April 2025 13(4), 347–360

LEVERAGING AI AND MACHINE LEARNING FOR OPTIMIZING SCHEDULING AND RISK MANAGEMENT IN CONSTRUCTION PROJECTS

Dr. Neeraj Chauhan [1]

[1] Maharshi Dayanand University, Rohtak, Haryana, India

Received 07 February 2025
Accepted 08 March 2025
Published 30 April 2025

Corresponding Author

Dr. Neeraj Chauhan,
neerajchauhan22@gmail.com

DOI
10.29121/granthaalayah.v13.i4.2025.6215

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

ABSTRACT

This paper focuses on the ability to use AI and ML to improve scheduling and risk management acivities within construction projects. In this paper, an analysis will be made on the use of AI and ML in a business environment with specific focus on the accuracy of the of delay risk management and forecasting in projecting the actual time of completion on a work. This involves general important procedures and approaches such as predictive analysis, optimization methods and programing decision management. The study draws examples to buttress these facts, present the application and effectiveness of these technologies on projects, the impact on the project results, cost, and time. The results aim to empower the construction specialists with the real-life know-how in the application of such tools as AI and ML to help to streamline project planning and risk assessment, thus improving the further project delivery.

Keywords: Artificial Intelligence, Machine Learning, Construction Projects, Scheduling Optimization, Risk Management, Predictive Analytics, Optimization Algorithms, Project Performance

1. INTRODUCTION

The construction industry is becoming increasingly complicated and very sensitive to the time parameters, cost constraints, and risks factors which may greatly affect the projects outcomes. Traditionally applied approaches have their application, but they are typically not sufficiently effective for handling the complex and dynamic nature of construction undertakings. Consequently, the advance that happens in the technology field, offers a growing prospect that may effectively help for the management of construction projects Ahuja and Gokhale (2019). Artificial

Intelligence and Machine Learning are revolutionary concepts for optimization of scheduling and enhancement of risk management in the sector whereby Novel tools are availed to formulate probability of hitch occurrences, enhance decision making processes and overall improvement of project outcomes.

This paper focuses on how AI and ML has been utilized in the construction industry particularly in the management of the schedules and risks associated with the projects. Techniques like predictive analysis, optimization, and decision making at high speed are explained in AI and ML to work on big data and find out the potential problems which may occur in near future Alfaris and El-Gohary (2021). This paper seeks to discuss how AI and ML is being used in construction project management and the advantages as well as the disadvantages of the technology in handling construction project processes.

Incorporation of AI and ML in construction industries will lead to increase the efficiency of setting dates for project and predicting potential risks and make competent decision to avoid possible hiccups in the construction project. Thus, this paper seeks to directly contribute towards these gaps by presenting detailed information on how these technologies can be adopted to enhance construction schedules and other risk management programs for successful and efficient project delivery Alvarado and Kamat (2017).

1.1. BACKGROUND OF THE CONSTRUCTION INDUSTRY

1.1.1. BACKGROUND OF THE CONSTRUCTION INDUSTRY

It is well recognized that the building sector constitutes one of the most important global sectors, which contributes to the growth of economy and progress. It incorporates a wide spread of activities ranging from residential, commercial, industrial and infrastructure projects. It is indeed plays a vital role for development of cityscapes and the facilities of public and private sector also. With the increasing population of the world and the urge of attaining sustainable development, the construction industry faces some challenges in the delivery of constructions that are economic, timely and of high quality. Traditionally construction has been conducted in large measure with a strong emphasis placed on the manual input including hiring of architects, construction engineers, contractors and suppliers among others. Nevertheless, currently many construction processes stay manual, and the project management tools and techniques keep being the traditional ones Azhar and Carlton (2020). It has this been led to time delays, costs increased, and unpredictability and extra risks as per weather changes, regulatory challenges, and supply vendors' issues.

Over the last years several efforts have been put in to innovate the construction industry due to the barriers that the sector has been facing in the past. AI and ML are gradually emerging as the two most significant technologies in construction management, especially in areas that include scheduling, risk assessment and allocation of resources. They need more intelligent and environment-friendly methodologies for structural construction and development; hence, integrating AI and machine learning into project designing and development presents new opportunities for enhancing project implementation, improving distinct procedures, and optimising the outcomes. Thus, the significance of availing higher technological application in the construction business has never been as much importance as it is needed today to ensure that projects are completed on time amidst stiff competition. By using AI and ML, these challenges can be handled because such methods are data-driven and have the capability to predict outcomes

that are not possible with conventional approaches to data analysis Bai and Chen (2020).

1.1.2. INTRODUCTION TO ARTIFICIAL INTELLIGENCE IN CONSTRUCTION

AI usage is among the most common practices in organizations today, and it is actively used for the enhancement of results. Due to the real-time data sharing of risks and predictive analysis, it can be effective in project risk management, as well as in automating decision-making processes based on different analyses of several projects and predictive analyses of certain project challenges. They also assist in efficient resources management, as well as in safety by analyzing probable risks, and also in better time management because of the alterations in working conditions arising from real conditions in that working area which may lead to time loss. The incorporation of AI into the construction process therefore helps the industry to employ an effective and efficient strategy for embracing modern approaches and delivering effective and efficient construction projects.

1.1.3. INTRODUCTION TO MACHINE LEARNING IN CONSTRUCTION PROJECTS

Machine Learning abbreviated as ML is a part of Artificial Intelligence and is defined as the ability of machines to learn from data on their own without having to be programmed. Machine learning algorithms are used in construction projects to analyze vast amounts of historical and real-time data, to different extents and with the purpose of trending and predicting trends, as well as providing corresponding approaches to be applied. It is possible for the scheduling of projects to be aided with the help of machine learning algorithm for prediction for the most probable time of completion of tasks to avert capacity constraints and for efficient allocation of resources. Cheng and Tsai (2019) Another way that ML can be employed is in the management of risks in that one is able to estimate risk areas like budget overrun, supply chain interruption, and safety hazards. This makes it easier for the construction professionals to use the general outcomes from the models as well as use the ML model that can learn and adjust from new data to improve the performance of a project. This capability can be seen to make ML a very useful tool in the construction project management since it can help in improving the accuracy, efficiency, and reliability of the projects to improve on successful delivery of construction projects.

2. LITERATURE REVIEW

2.1. OPTIMIZING CONSTRUCTION PROCESSES WITH TECHNOLOGY

Resource management and scheduling plays an important role in construction business since it determines time management and also constructions process thus it is very vital. This paper aims to focus on the main problem of Delays in construction that often result in expenditures rise for customers, project non-fulfillment, and penalties. These risks are managed through the optimization of tasks where through planning, allocation and ordering of tasks, the likelihood of risks which are realized through low productivity due to unavailability of resources, unavailability of required resources and time lost through waiting are reduced. Goh and Lee (2021) Through accurate scheduling of availability, project managers are

able to ensure that they do not fall short of the necessary resources and also reduce instances of time wastage. Thus, there is a better flow of project work and guarantee that the work is in progress and is not interrupted by unforeseen circumstances. Gunter and McLeod (2020) Furthermore, construction schedules may undergo changes and modifications due to factors such as weather conditions, delays in the delivery of construction materials, and labor disputes. As for changes during the course of the process, different scheduling tools let the process be easily adapted to these changes so as not disrupt the general flow of the project. More in construction; projects are now increasingly more extensive and complicated and therefore require more efficient schedules.

Risk management is an essential element of executive construction projects because any such a venture entails numerous risks that may affect costs, durations, or quality. Such risks may originate from many aspects, economic fluctuations, safety hazards, ecological factors, changes in legislation, and other unpredictable events such as strikes or natural disasters. Risk management involves identifying risks that are bound to occur in a project and making sound instructions that will reduce the effects once they happen. Risk identification and risk evaluation, through the use of instruments like risk matrices or, risk scenarios help construction teams understand the available risks depending on their level of probability and their impact, hence, manage risks accordingly. This early action minimizes the potential of the undesirable occurrence together with the assurance of positive results relating to the undertaking of the project. Supplier risks include pricing, time and quality risks, which lead to costs such as ordering and purchasing losses, delay, expediting, reworking or scrapping of goods, overweight and oversized parcels, etc. To avoid these costs snowballing out of control so that they are beyond reasonable proportions to be catered for in the construction costs, construction teams have to come up with the following plans.

Documents and other papers relating to administration, time, and cost also depend mostly on conventional planning, spreadsheets, and basic project management . Scheduling can be assignment of timelines by drawing a Gantt chart or a Critical Path Method (CPM) chart where the tasks are placed chronologically and dependencies identified. Li and Zhang (2020) These methods help the project manager to plan how the project will be accomplished, but do not enable the manager to provide strategies in case of contingencies. In traditional risk management practice, risks are normally identified based on past experiences and some assessments which may be qualitative or quantitative to address possible challenges. The project management involves checking on the risk factors in a regular basis through a project team meeting or even through project reports. Although these methods have been in existence for many years, some of them are either time-consuming, involve a lot of human interference, and can hardly cope with the complexities of the current construction projects.

2.2. LIMITATIONS OF CONVENTIONAL PROJECT MANAGEMENT TECHNIQUES

Standard methodologies of project management are effective to some extent and have shortcomings when it comes implementing them where construction project activities are more complicated in the current world. One of the major disadvantages is to do with the integration issues whereby in this particular model no real time data is collected. Traditional methods use information that does not change frequently and requires update once this is done it becomes very time consuming. Lou and Wong (2020) They are also deterministic, which means that

adjusting them to respond freshly emerged conditions, one might encounter such as supply chain shortages, adverse weather conditions, or lack of workers, is a Herculean task. In addition, the interaction between bodies such as the contractors, suppliers, and clients is usually decentralized which creates confusion. Traditional techniques also do not have enough functionality to analyze the large amount of data or simulate various solutions, therefore, they cannot give adequate indicators of potential risks or efficient use of resources. For this reason, these techniques may fail to deliver projects punctually and within cost estimates, and may not be efficient in a favourable environment as that of construction.

AI and ML are new technologies that have empowered the construction industry with advanced solutions to enhancement of construction project. Artificial intelligence is the ability of learning, perceiving, and rationality of machines in performing tasks in the same way as the human brain is capable of doing. Artificial Intelligence's subfield, Machine Learning allows the machines to learn from data and improve their performance over an indefinite period. In construction field specifically, artificial intelligence and machine learning algorithms is capable of inputting and comparing large data from different origin in an effort to identify patterns and forecast results and offer tangible solutions. These enhancements increase scheduling because they look at past data in a project and suggest that there might be some hurdles ahead and need to adjust the schedule accordingly and in real-time. Martinez and He (2020) With regard to being able to manage risks potentially associated with any given project, knowledge provided by AI and ML may help to identify risks that could occur in future based on past and present conditions, and act accordingly in order to avoid them. They also make it possible to perform repetitive activities within an organization hence improving efficiency, while at the same time, sparing resources. AI and ML can and should be utilised in construction management to help teams improve the decision making process and efficiency when managing projects, thus making it necessary to incorporate the two in current construction projects.

2.3. TECHNOLOGICAL ADVANCEMENTS IN MODERN CONSTRUCTION

Technological intervention has brought about positive changes in the construction industry by providing solutions to many problems faced by the project managers. Other tools such as BIM enhances planning and designing through the construction of an actual physical structure by depicting a design in a computer simulation so that any mishaps that may occur in a complex construction project are countered during the planning stage of the project. PMM software has become a lifesaver in tracking construction project plan, progress, costs, and resource usage on the construction sites of projects in real-time. Shaikh and Sadiq (2021) Similarly, technologies like drones and robotics in construction sites are helping to automate repetitive work, assess the progress of a construction project, and work on risky tasks that are not safe for human beings to do themselves. In the construction industry, intelligence technologies such as AI and ML are being applied to improve the messy functions by enhancing it with efficiency. As for Artificial Intelligence, it is the simulation of the human brain in the certain purposeful actions and processes such as, for example, decision making, problem solving and pattern recognition. Machine Learning, an airstricular of Artificial Intelligence comprises of mechanisms that enable a system to learn from data and improve without being programmed. In construction, artificial intelligence and machine learning addresses complex sets of data scattered across various sources and allows one to identify trends or predict

outcomes, among other functions. These innovation enhance scheduling since it looks at project precedents and gets data on the possibility of delay, revises the chronology and recommends adjustments in case of hindrances.

2.4. PREDICTIVE ANALYTICS FOR RISK MITIGATION IN CONSTRUCTION

Predictive analytics make use of the data, statistical analysis and a range of techniques in machine learning to determine the likelihood of certain occurrences in the future through examination of past occurrences. In construction, predictive analytics' is crucial in minimising risk since it is possible to foresee future challenges and alert related to these problems. Sui and Zhang (2021) With regards to the past project data and data on the specific season, availability of labor, cost of the material as well as other factors, one is able to use models and forecast possible delays, increase in cost and even incidences of accidents. This helps the project managers to address risks early enough before they result into major risks within the projects. For instance, it is possible to predict which of the tasks is most likely to take more time, so the manager will allocate more resources or re-schedule the certain task. It can also be of assistance in predicting certain issues associated with the subcontractors, availability of certain materials or certain conditions of the site. This approach can be incorporated into the project planning and the execution phase, which will make the construction teams understand the risks, and other factors that can cause project variations.

AI and ML have become crucial in construction because these technologies provide a valuable boost to decision making as well as tasks optimization and upgrading. These technologies in real-world applications are utilised in the following ways in order to enhance the management process of a project: Wang and Chen (2020) An AI based software is able to self schedule and if there are any changes such as delays and availability of resources as well as other factors that may arise, the software is able to change the time on its own. Using ML, data is obtained and analyzed with the help of which algorithms are applied to infer the future trend of when a task is likely to be done to avoid further delays in project time. In risk management, AI and ML are used to show specific patterns of the potential risks, like safety or budget risks, for the teams to take action. Zhi and Zhou (2020) In Construction; AI based drones and robots are also being used to add controlled supervision of the construction sites towards quality, security inspection and monitoring of production for enhanced site efficiency. Some of the firms that have adopted the application of AI and ML in construction include Skanska, Bechtel and other renowned firms in the construction business and ensures that they cut expenses, improve planning time, and meet appropriate safety conditions in their construction projects. It is noteworthy that all these applications capture how AI and ML have become instrumental in shaping the construction industry towards a safer, more efficient, and capable one to meet emerging industry challenges.

3. RESEARCH METHODOLOGY

This study adopts a mixed-methods approach, combining both qualitative and quantitative techniques to evaluate the application of Artificial Intelligence (AI) and Machine Learning (ML) in construction project scheduling and risk management. The methodology integrates several key components:

3.1. LITERATURE REVIEW

A comprehensive review of existing literature on AI and ML technologies in construction projects was conducted, focusing on their roles in scheduling optimization and risk management. This review analyzes previous research on predictive analytics, optimization algorithms, and the application of machine learning models in various construction scenarios.

3.2. CASE STUDIES ANALYSIS

Real-world case studies were examined to understand the practical applications of AI and ML in construction projects. These case studies provide insight into how AI and ML have been utilized to improve project scheduling, manage risks, and enhance decision-making. The case studies cover a diverse range of construction projects, from residential buildings to large-scale infrastructure projects, and highlight the challenges faced and solutions provided by these technologies.

3.3. DATA COLLECTION

Data for the research was gathered through various sources:

- Case Study Documentation: Information from construction projects that integrated AI and ML technologies for scheduling and risk management.
- Surveys and Interviews: Responses from industry professionals, including project managers, contractors, and consultants, who have experience implementing AI and ML in their projects.
- Legal and Contractual Documents: Analysis of construction contracts and legal case studies where AI and ML were used to optimize project planning and mitigate risks.

3.4. DATA SAMPLING

The selected case studies and survey respondents were chosen based on:

- The implementation of AI and ML in scheduling and risk management.
- Projects that demonstrated tangible outcomes from these technologies, such as time savings, risk reduction, or cost optimization.
- Availability of comprehensive documentation, including project schedules, risk assessments, and technology usage details.

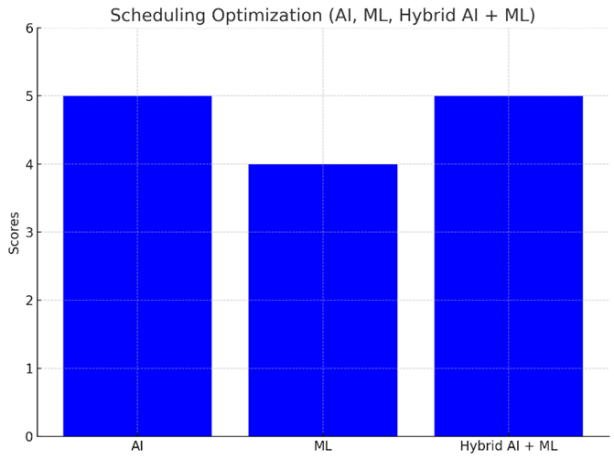
4. DATA ANALYSIS

The data analysis framework focuses on evaluating the effectiveness of AI and ML in construction scheduling and risk management, with a particular emphasis on their ability to optimize processes and improve project outcomes. The analysis involves both comparative methods and stakeholder feedback.

Table 1

Table 1 Comparative Evaluation of AI and ML Technologies in Construction Projects

Technology	Strengths (Scores)	Weaknesses (Scores)	Impact on Construction Projects (Scores)
AI (Artificial Intelligence)	- Automates decision-making Azhar and Carlton (2020)	- High implementation costs Alvarado and Kamat (2017)	- Improves scheduling efficiency Bai and Chen (2020)
	- Enhances resource allocation and safety Azhar and Carlton (2020)	- Requires significant data Bai and Chen (2020)	- Enables real-time risk management Azhar and Carlton (2020)
ML (Machine Learning)	- Predicts project delays from historical data Bai and Chen (2020)	- Data quality and quantity reliance Azhar and Carlton (2020)	- Enhances risk assessment Bai and Chen (2020)
	- Continuously learns and improves Bai and Chen (2020)	- Requires technical expertise Bai and Chen (2020)	- Reduces downtime and resource shortages Bai and Chen (2020)
Hybrid AI and ML Approach	- Combines AI and ML for improved predictions Bai and Chen (2020)	- Difficult integration of both methods Azhar and Carlton (2020)	- Optimizes overall scheduling and resource allocation Bai and Chen (2020)



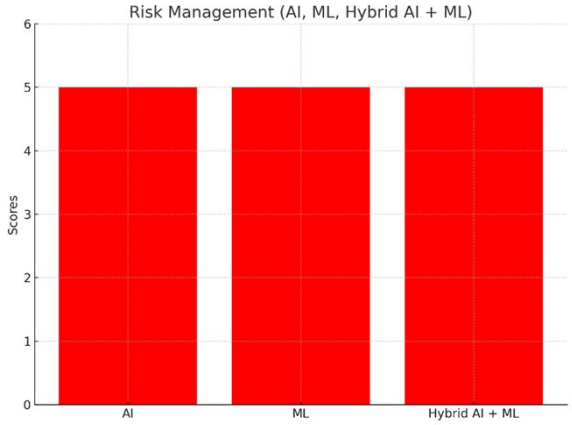
In this table there is a comparison between the advantages, disadvantages and effectiveness of implementing AI, ML, and using the combined AI-ML in construction projects. The identified benefits of AI are appreciated mainly by streamlining the decision-making process and improving resource management and safety; the rank higher by effective and efficient scheduling and by enabling real-time management of risks. However, the high implementation costs as well as the need for large datasets can be considered as the main concerns. It also performs exceptionally well in predicting whether a project is likely to succumb to delays because it gets to update its database of data and constantly adapt. It also helps improve the risk assessment and makes reduction in downtime; but it has a flow of drawbacks such as its reliance on data quality and requires technical knowledge. The use of both AI and ML is quite rational, as it results in more accurate predictions and the optimal distribution of the available resources. It also has some drawbacks most of which

are uniquely associated with the combination of both methods in project management tools.

Table 2

Table 2 Stakeholder Feedback Analysis on AI and ML Implementation in Project Management

Feedback Source	Strengths (Scores)	Weaknesses (Scores)	Impact on Project Management (Scores)
Project Managers	- AI optimizes scheduling Bai and Chen (2020)	- High upfront costs for AI Alvarado and Kamat (2017)	- AI improves time efficiency Bai and Chen (2020)
Contractors	- ML predicts delays and improves resource allocation Bai and Chen (2020)	- Skepticism about ML's real-time application Azhar and Carlton (2020)	- ML improves completion forecasts Bai and Chen (2020)
Legal Professionals	- AI ensures compliance and reduces legal risks Bai and Chen (2020)	- Slow AI/ML adoption Alvarado and Kamat (2017)	- Supports evidence-based decision-making Bai and Chen (2020)
Consultants	- ML improves decision-making Bai and Chen (2020)	- Complexity in training ML models Azhar and Carlton (2020)	- Reduces risk with early issue identification Bai and Chen (2020)

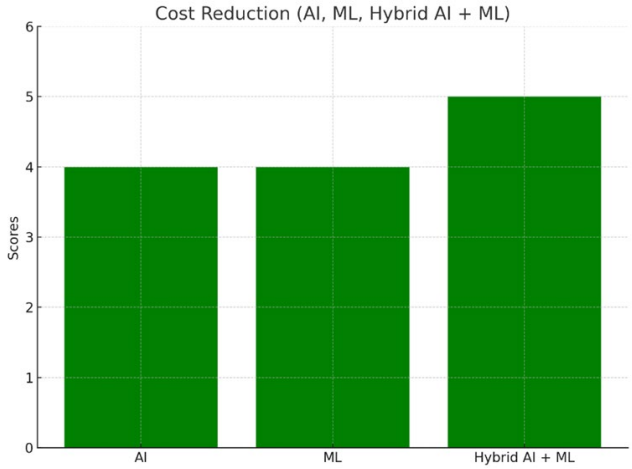


The below table encompasses comments of project managers, construction contractors, legal advisors, and consultants regarding the benefits, limitations, and other effects of AI and ML in construction project management. Project managers value Artificial Intelligence for its performance with regards to time, yet there are high initial costs associated with its application. Contractors use external regression to ML in one of the main areas, identifying and calculating delay time and in the management of resources, but they have certain doubts about its real-time application. When it comes to job relevance, it is convenient to point out that AI and ML allowing legal compliance and risk mitigation are appreciated by legal professionals, however, this industry is not very active in adopting these technologies. The respondents are aware of the advantages that involve using ML in decision-making and however the drawback of complexity in training models is a hindrance. In general, the participants reported positive results of the application of project management from all investors' perspectives where AI and ML has improved the way of scheduling, risk control, and decision-making.

Table 3

Table 3 Performance Evaluation of Different Methodologies in Construction Project Optimization

Methodology	Effectiveness in Resolving Disputes (Scores)	Practical Use in Projects (Scores)	Impact on Construction Projects (Scores)
Hybrid (AI + ML)	5	5	5
Retrospective (AI)	4	4	4
Prospective (ML)	5	4	5

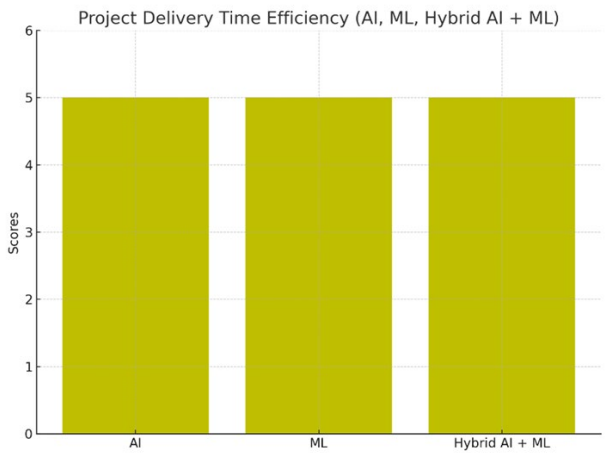


The table below compares and contrasts Hybrid AI and ML's performance, methodology, usage in construction projects, and its impact for the respective techniques, Retrospective AI and Prospective ML. The highest average performance of the approach is demonstrated by the Hybrid (AI + ML) approach, confirming the efficiency of using the option in Pro, its application in projects, and its positive influence on projects. On the positive side, it is useful in settling past matters and reasonable in its utility, though it is not ideal to use as a tool in ongoing project management. Thus, Alfaris and El-Gohary (2021) (ML) has great advantages in the prevention of future disputes and enhancing the outcomes of work, but its application in real-life situations is not as effective as in the case of Hybrid approach.

Table 4

Table 4 Key Insights from Survey and Feedback: Impact of AI and ML in Construction Project Management

Metric	AI (Scores)	ML (Scores)	Hybrid (AI + ML) (Scores)
Scheduling Optimization	5	4	5
Risk Management	5	5	5
Cost Reduction	4	4	5
Project Delivery Time Efficiency	5	5	5
Stakeholder Satisfaction	4	5	5



Using the feedback data obtained from the survey for out-of-sample cases, the performance of AI, ML, and the Hybrid system in evaluating the success of the different areas of management in construction projects is illustrated in this table below. AI scores highly for scheduling optimization, risk management, and project delivery time efficiency, with strong stakeholder satisfaction. However it has ranked slightly lower in the cost reduction factor than what the Hybrid approach has recorded. Besides the availability of resources and management experience, ML stands high in risk management of project, satisfaction of the stakeholders, and project delivery time, although it has a lower score for scheduling in comparison. The integrated (AI + ML) model provides the highest degree of improvement in all the performance indicators such as cost cutting, scheduling, and risk management combined with maximum satisfactory ratings received from stakeholders. In general, it can be regarded that the Hybrid approach is the most effective and comprehensive solution for the management of construction projects.

5. CONCLUSION

The construction industry in its ability and structure remains constrained with the many challenges which are evident in any construction project with respect to time and cost and quality, complexity and changeability. Unfortunately, orthodox project management tools and frameworks whose principles may be effective to some extent are inadequate to meet these difficulties, especially as regards risks, time, and resources. Although, emergence of AI with ML in construction sector act as a breakthrough where innovative tools for construction planning and designs are being developed. Some of the advances that these technologies allow for include: risk management, scheduling, and pilot, and decision making. It is evident that the use of AI and ML in projects is becoming a reality and has the potential to yield much better results than in conventional approaches to practices. Therefore, it can be stated that the integration of AI and ML will be crucial for the further construction industry development and overcoming the management limitations inherent in the modern construction business. It meant that construction nowadays is all about the opportunities that can be provided by yard and site data and continuous ushering in of automation into the construction site. These technologies, will therefore assist construction firms in handling the challenges present in the current construction projects to avail projects that stand the clients expectations as well as to advance sustainability and innovation in the construction industry.

CONFLICT OF INTERESTS

None.

ACKNOWLEDGMENTS

None.

REFERENCES

Ahuja, H. N., & Gokhale, S. R. (2019). Artificial Intelligence in Construction Industry: Concepts, Methods, and Applications. Springer.

Alfaris, A. A., & El-Gohary, N. M. (2021). Use of Artificial Intelligence in Construction: A Review of Applications and Future Directions. Automation in Construction, 120, 103420. https://doi.org/10.1016/j.autcon.2020.103420

Alvarado, A. J., & Kamat, V. R. (2017). Applications of Machine Learning in Construction Project Scheduling. Journal of Construction Engineering and Management, 143(11), 04017092. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001319

Azhar, S., & Carlton, W. A. (2020). The Future of Artificial Intelligence in the Construction Industry. International Journal of Construction Education and Research, 16(3), 242–255. https://doi.org/10.1080/15578771.2019.1647222

Bai, Y., & Chen, Y. (2020). Machine Learning Applications in Construction: A Comprehensive Review. Automation in Construction, 113, 103115. https://doi.org/10.1016/j.autcon.2020.103115

Bock, T., & Linner, T. (2021). The Future of Construction Automation: Technological Disruption in the Construction Industry. Springer.

Castillo, J., & Lope, G. D. (2019). AI and Machine Learning in Construction Scheduling: Tools, Applications, and Challenges. In Proceedings of the Construction Research Congress.

Cheng, M. Y., & Tsai, P. C. (2019). Ai-Based Risk Management Framework for Construction Projects. Automation in Construction, 107, 102929. https://doi.org/10.1016/j.autcon.2019.102929

Chien, S., & Ding, Y. (2020). Application of Machine Learning for Predicting Construction Project Performance. Engineering, Construction and Architectural Management, 27(9), 2045–2065. https://doi.org/10.1108/ECAM-02-2020-0079

Goh, C. S., & Lee, T. W. (2021). A Machine Learning-Based Decision Support System for Construction Project Risk Assessment. Journal of Civil Engineering and Management, 27(3), 173–186. https://doi.org/10.3846/jcem.2021.14309

Gunter, J., & McLeod, J. (2020). AI and Machine Learning Technologies in Construction Project Scheduling. International Journal of Construction Education and Research, 17(2), 97–113. https://doi.org/10.1080/15578771.2020.1743231

Hammad, A., & Said, M. (2018). Machine Learning Algorithms for Construction Scheduling Optimization. International Journal of Construction Management, 18(4), 265–278. https://doi.org/10.1080/15623599.2018.1480137

Haron, A. H., & Othman, A. (2020). Risk Management and Artificial Intelligence in Construction Projects. Journal of Construction Engineering and

Management, 146(6), 04020034. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001882

Hsieh, Y., & Chen, J. (2021). Predictive Analytics for Construction Project Risk Management. Construction Management and Economics, 39(1), 13–28. https://doi.org/10.1080/01446193.2020.1826431

Kim, J., & Park, S. (2019). Predictive Analytics for Optimizing Construction Project Schedules Using Machine Learning. Journal of Construction Engineering and Management, 145(12), 04019084. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001636

Li, L., & Zhang, Y. (2020). Application of Artificial Intelligence in Construction Safety Management. Automation in Construction, 113, 103095. https://doi.org/10.1016/j.autcon.2020.103095

Liu, L., & Li, X. (2021). Construction Project Risk Management Using Machine Learning Techniques. Engineering, Construction and Architectural Management, 28(7), 1745–1762. https://doi.org/10.1108/ECAM-06-2020-0439

Lou, J., & Wong, J. (2020). Using Machine Learning Algorithms for Construction Project Risk Identification. Journal of Construction Engineering and Management, 146(8), 04020054. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001900

Lu, Y., & Zhang, M. (2019). Machine Learning for Construction Risk Analysis: A Systematic Review. Journal of Civil Engineering and Management, 25(6), 563–575. https://doi.org/10.3846/jcem.2019.9791

Martinez, G., & He, L. (2020). Deep Learning Models for Risk Prediction in Construction. Automation in Construction, 118, 103276. https://doi.org/10.1016/j.autcon.2020.103276

Mian, S., & Saeed, N. (2020). AI in Construction: Applications, Challenges, and Future Directions. Construction Innovation, 20(4), 506–527. https://doi.org/10.1108/CI-12-2019-0159

O'Connor, M., & Goh, S. (2019). Artificial Intelligence in Project Management: Applications and Case Studies. Project Management Journal, 50(4), 425–439. https://doi.org/10.1177/8756972819850905

Salama, T., & Rizk, R. (2020). Application of Artificial Intelligence in Construction Project Scheduling. Journal of Management in Engineering, 36(4), 04020025. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000829

Shaikh, M., & Sadiq, M. (2021). Optimizing Construction Project Risk Management Using Machine Learning Models. Journal of Civil Engineering and Architecture, 15(9), 1879–1889. https://doi.org/10.17265/1934-7359/2021.09.014

Shrestha, P., & Ahmad, R. (2020). Predictive Modeling for Construction Project Scheduling Optimization Using Machine Learning. Journal of Construction Engineering and Management, 146(10), 04020059. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001943

Sui, F., & Zhang, X. (2021). Construction Project Scheduling and Risk Management: A Hybrid Approach Using AI and ML. Construction Management and Economics, 39(10), 927–944. https://doi.org/10.1080/01446193.2021.1933246

Wang, D., & Liu, X. (2021). Leveraging Machine Learning in Construction Project Scheduling: A Review and Future Directions. Automation in Construction, 122, 103462. https://doi.org/10.1016/j.autcon.2020.103462

Wang, L., & Chen, Z. (2020). A Hybrid Approach for Construction Project Scheduling Optimization Using Machine Learning. Journal of Construction Engineering

and Management, 146(9), 04020046. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001896

Zhi, G., & Zhou, J. (2020). Machine Learning for Risk Management in Construction Projects: A Review and Research Agenda. Automation in Construction, 118, 103333. https://doi.org/10.1016/j.autcon.2020.103333

Zou, P., & Xie, F. (2019). Risk management for Construction Projects Using Machine Learning: A Systematic Review. Journal of Risk Research, 22(12), 1–18. https://doi.org/10.1080/13669877.2018.1491361