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Artificial Intelligence–Driven Intelligent Project Management: An Integrated Framework for Planning, Scheduling and Control in Engineering and Construction Projects

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Abstract

The implementation of AI in engineering and construction is transforming project management practices, with sophisticated forecasting, optimization and real-time decision-support tools. The current studies, however, tend to investigate the applications of AI in the areas of project planning, scheduling and control independently from each other as functional domains and only a few studies focus on analytical frameworks that attempt to explain the synergistic effects of these various integrated applications on intelligent project management systems. A structured literature review is used in this study to analyze the latest progress of AI applications in project planning, scheduling and control. The literature, across engineering, construction management and project management, was analysed and the most prevalent technologies and implementation trends, organizational factors and performance impacts of AI adoption were identified. Thematic synthesis results are applied in this paper to propose an Integrated Artificial Intelligence Project Management Framework (IAIPMF) that integrates predictive planning, adaptive scheduling, intelligent project control, organizational readiness and governance mechanisms in one analytical framework. The study contributes theoretically to project management research and provides practical guidance for organizations implementing AI-enabled project management systems.

Keywords: Artificial intelligence; Project planning; Project scheduling; Project control; Construction management; Digital transformation

Introduction

The complexity of engineering and construction projects is increasing with larger projects, greater technological complexity, a greater multiplicity of stakeholders and greater unpredictability in economic and environmental factors. The key to delivering such projects on time, on budget and to quality lies in proper planning, scheduling and control. Even after decades of methodological progress, there is still significant reporting on project failures, including delays, cost overruns and performance inefficiencies.

Conventional project management software, such as the critical path method, program evaluation and review technique, earned value management, *etc.*, is also criticized for being static and not dynamic enough to adapt to changing project conditions.

Digital transformation has, in recent years, changed the way projects are conceived, managed and delivered. Artificial intelligence has been a popular topic among new digital technologies because of its ability to work with large amounts of data, extract patterns and assist in making complicated decisions. Artificial Intelligence is a very general area of practice that includes techniques like machine learning, neural networks, expert systems and evolutionary algorithms that augment or replace human decision making. In the context of project management, AI can improve forecast precision, optimize resource utilization and proactively manage projects. AI has been gaining momentum in project management research, but current studies focus on the aspects of project management where AI is present, such as planning, scheduling

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or project control, individually. In contrast, fewer studies have a project management perspective that spans a range of concepts that account for the interactions between predictive planning, adaptive scheduling, intelligent monitoring, organizational readiness and governance mechanisms. In addition, minimal work has been done in conceptualizing and linking the technical aspects of AI to managerial, organizational and ethical aspects that affect the adoption of project management. This disintegration hampers the building of a coordinated AI integration approach in engineering and construction project contexts.

Therefore, the present study introduces an Integrated Artificial Intelligence Project Management Framework (IAIPMF) for engineering and construction project management to fill this research gap. The literature reviewed contained literature on the use of AI in specific areas of project management, but there was no systematic research that analyzed the impact of AI on planning, scheduling and control processes. Most studies are either scattered or too specialized and are applicable only to project managers and decision makers. This gap is addressed in this paper by discussing the impacts of artificial intelligence on the fundamental processes of project planning, scheduling and control in engineering and construction projects.

The goal is to delve into the benefits, challenges and implications of integrating AI into the world of project management. The rest of this paper is organized as follows. The literature review of project planning, scheduling, control and application of artificial intelligence is discussed below. The research methodology is then presented and research findings are provided and discussed. Finally, the results are summarized from a practical, theoretical, limitations and future research perspectives at the end of the paper.

Literature Review

Project planning, scheduling and control

Project planning and scheduling and project control are the main pillars for effective project management. Planning involves outlining a project's goals, scope, resources and plans to achieve the project's outcomes. Scheduling transforms project plans into processes of activities over time and control keeps track of the project implementation and makes changes when necessary to meet the intended project outcomes.

The use of traditional planning and scheduling methods has been very popular due to their simplicity and standardized nature [1]. These approaches make the assumption of a steady state and may not consider unpredictability, dependencies or dynamics. Weather conditions, labour productivity, disruption in the supply chain and changes in the design are some of the uncertainties that affect deterministic planning models in construction and engineering projects. The mechanisms for project control periodic reporting and manual interpretation have a tendency to report on problems at too late a stage to be corrected with remedies. The limitations of traditional project management methodologies become more apparent with the growth of scale and complexity of projects.

Artificial intelligence in project management

AI is a system of computation that can be used to accomplish tasks that are typically done by humans, including learning, reasoning and problem-solving. Artificial Intelligence (AI) has been extensively explored in project management for enhancing decision quality and operational efficiency [2]. Historical data from projects can be used in a machine learning algorithm to make predictions about future project cost overruns and schedule delays and complex constraints can be used in an optimization algorithm to generate optimal resource allocation strategies.

The digital information on a project generated by building information modelling, sensors and project management software are increasingly accessible and this is how the use of artificial intelligence in project management is informed. These data sources enable the development of intelligent systems that can learn from past projects and adapt to the current project conditions [3]. Although this is possible, the adoption of artificial intelligence in project management processes is uneven, as levels of adoption differ between organizations and project types.

Artificial intelligence in project planning

Artificial intelligence has shown great potential for improving project planning by enabling better predictions and strategic decisions. Compared to classical parametric models, machine learning models can use historical data to more accurately predict project duration, cost and risk [4].

These models can help describe non-linear relationships and intricate interactions among project variables that are often ignored in traditional methods. Artificial intelligence has been applied in construction projects to aid in the early planning stage by assessing alternative design and construction plans. Search algorithms are used to find resource-efficient plans that take into account various goals, including cost reduction and maximum productivity [3]. Scenario analysis is also aided by artificial intelligence, which helps planners evaluate how uncertainties and disruptions affect project outcomes.

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Artificial intelligence in project scheduling

One of the most complicated parts of project management is scheduling, as it is dynamic and vulnerable to uncertainty. Genetic algorithms and reinforcement learning are artificial intelligence methods that have been used to produce optimal schedules that adapt to evolving conditions [5].

In contrast to classical scheduling methods that rely on fixed schedules and assumptions, artificial intelligence-based methods can update schedules in real time using available information. Predictive scheduling models help managers to foresee delays and take corrective measures before they happen.

A machine learning model based on historical project data can identify early signs of project schedule slippage and take action to remedy the situation. These skills are particularly valuable in more intricate engineering endeavors where one task's delay impacts another's schedule.

Artificial intelligence in project control

Project control aims to track project performance and take corrective measures to put the project back on track. AI enhances project management by monitoring in real-time, detecting anomalies and predicting project performance.

The key performance indicators and deviations from planned targets can be automatically monitored through smart control systems [2]. In the construction management sector, digital technology has been utilized through the use of Artificial Intelligence (AI) and digital tools, including BIM, for real-time access to project performance [6].

Predictive control models are used to predict future performance using the current trends and proactive measures by the project managers can be taken. These systems reduce the need for manual reporting and subjective judgements, leading to better control decisions and greater accuracy and timeliness.

Research gaps

The use of AI in project management is gaining momentum, but literature on the subject often deals with specific tasks or the technical aspects of using AI. Planning, scheduling and control from the perspective is not always explicitly defined, nor is there a clear explanation of its implications for project managers [6]. There is lack of comprehensive study of issues related to organizational preparedness, data management and ethics. The paper aims to fill these gaps by offering a comprehensive analysis of the effects of artificial intelligence on the key project management functions.

Research Methodology

This research paper uses a structured literature review to systematically investigate the impact of artificial intelligence on project planning, scheduling and project control processes in an engineering and construction management context. To ensure methodological rigor, transparency and replicability and to assist with a synthesis of recent developments in this rapidly evolving area of research, the structured review method was selected. The literature review is particularly appropriate for interdisciplinary and fragmented research areas such as the application of artificial intelligence in project management, which is performed in the fields of construction management, information systems, operations research and data science [7]. The review process was done based on the guidelines of the systematic and structured literature review in the field of management and engineering research. Among the available data sources, academic databases like Scopus and Web of Science were selected as the main data sources because of the availability of a high number and quality of the peer-reviewed journals related to construction management, project management and artificial intelligence [8]. These databases are cited in engineering and management literature reviews as reliable sources and are used in publications in ECAM and other journals. The overall research methodology and conceptual structure adopted in this study are illustrated in **Figure 1**.

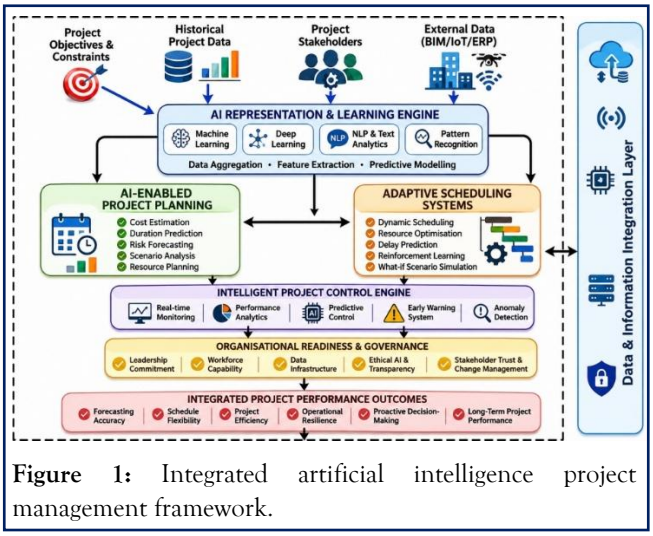

Figure 1: Integrated artificial intelligence project management framework.

The systematic review protocol employed in this research is summarized in **Table 1**.

Table 1: Structured literature review protocol.

Aspect	Description
Review approach	Structured literature review

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Databases	Scopus, Web of Science
Time period	2020–2025
Language	English
Document type	Peer-reviewed journal articles
Subject areas	Engineering management, construction management, project management, artificial intelligence
Search keywords	"Artificial intelligence", "machine learning", "project planning", "project scheduling", "project control", "construction project management"
Inclusion criteria	Studies addressing AI applications in project planning, scheduling and/or control within engineering or construction contexts
Exclusion criteria	Studies unrelated to project management, purely technical AI algorithm papers without managerial implications, conference papers and non-peer-reviewed sources
Screening process	Title and abstract screening followed by full-text review
Analysis method	Thematic analysis
Final sample	Studies focusing on AI-supported planning, scheduling and control in engineering and construction projects

The approach adopted was to seek out the most recent and relevant studies published from 2020 to 2025, which were considered to be the most up-to-date research on the subject of AI technologies and their application in project management. The keywords and search strings were composed of terms related to artificial intelligence, including artificial intelligence, machine learning, deep learning, predictive analytics and optimization algorithms, as well as project management terms such as project planning, project scheduling, project control, construction project management and engineering projects. The search was narrowed down using the Boolean operators to cover the application areas. After the first search, the articles were selected using a multi-stage selection process. To start with, titles and abstracts have been checked to eliminate studies that were evidently outside the research scope, such as those that focused only on software development projects or on the design of artificial intelligence algorithms without project management. Second, to assess the methodological quality and topicality, a full-text screening was conducted [9]. Peer-reviewed journal articles were only retained to be analyzed, but only those articles that were written in English and specifically covered the use of artificial intelligence in planning, scheduling or control of engineering or construction projects. The ultimate data set consisted of a wide range of literature, both empirical and conceptual, case studies and review articles. The multiple variations suggest the developmental and exploratory nature of AI research within project management. The selected articles were analyzed using thematic analysis to find the similarities between the articles, spheres of application, advantages and challenges in the adoption of artificial intelligence. Thematic analysis is used to combine qualitative and quantitative information from a diverse set of studies and is especially appropriate for summarizing research findings and pinpointing research gaps [10]. Themes were created by revising the literature for rigor in analysis. Special attention was given to the influence of artificial intelligence in decision-making processes in planning, scheduling and control processes and the influence of organizational and contextual factors on the implementation. This method of qualitative synthesis allows to get an overall picture of the state of knowledge and to indicate future directions of research and practice.

Thematic classification framework

To improve the analytical consistency, the literature selected was categorized into five major analytical themes:

Theme 1: AI-powered project planning and predictions;

Theme 2: Intelligent scheduling and optimization systems;

Theme 3: Project monitoring and control using AI;

Theme 4: Organizational readiness and human capability factors;

Theme 5: Governance, ethics and implementation issues.

A comparative thematic synthesis was then performed to reveal common modes of adoption, linkages across functions, barriers to implementation and research themes across AI-enabled project management studies.

Results and Findings

The literature review process is systematic, which reveals that there is a considerable positive impact of artificial intelligence on project planning, scheduling and control in the field of engineering and construction management. In every of the reviewed studies, AI is always associated with higher decision accuracy, improved adaptability and efficient decision-making in complicated and uncertain project environments [11]. The evidence is synthesized across all three

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project management functions and cross-functional themes to report the results of the project. The major artificial intelligence applications identified from the reviewed literature are summarized in **Table 2**.

Table 2: Artificial intelligence applications in project planning, scheduling and control.

Project Management Function	AI techniques applied	Key Applications	Main Benefits	Representative Studies
Project planning	Machine learning, neural networks, predictive analytics	Cost estimation, duration forecasting, risk prediction	Improved forecasting accuracy, enhanced decision support	Cheng et al.; Marzouk and Enaba; Kim et al.
Project scheduling	Genetic algorithms, reinforcement learning, optimization models	Dynamic scheduling, resource allocation, delay prediction	Increased schedule flexibility, reduced delays, better resource utilization	Wang et al.; El-Sayegh et al.; Li et al.
Project control	Machine learning, anomaly detection, decision support systems	Performance monitoring, cost control, early warning systems	Real-time control, proactive decision-making, improved project performance	Olawumi and Chan; Moselhi et al.; Sacks et al.

Artificial intelligence and project planning

The literature review reveals that the implementation of artificial intelligence in project planning has a positive impact, aiding in the prediction of future events and assisting in strategic decision-making. Construction and engineering projects have been traditionally planned using old methods that depend on historical averages and deterministic assumptions that do not capture the complexity and uncertainties of today's projects. With the use of artificial intelligence, specifically predictive models based on machine learning, planners have the opportunity to analyze huge and heterogeneous data, such as historical project data, design data and external environmental data, to produce more credible cost and duration estimates [12,13].

The application of artificial intelligence across various phases of the project life cycle is illustrated in **Figure 2**. A few studies have shown that AI planning models outperform parametric and regression models in predicting project outcomes. Two machine learning techniques that have been proven to model the nonlinear relationships among the project variables for higher quality estimates at an earlier stage are random forests and neural networks [14].

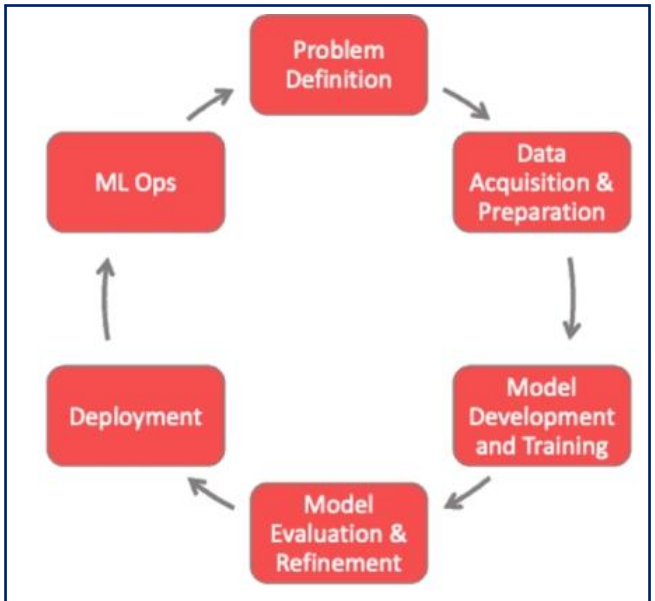

Figure 2: AI applications across the project life cycle.

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Accurately planned projects can help reduce the chances of costing overshooting and delays and give stakeholders a greater sense of confidence when considering the feasibility of a project.

In addition to forecasting, artificial intelligence can also be used to aid scenario analysis and optimization in the planning stage. By applying optimization algorithms to analyse multiple project strategies and to take multiple objectives into account, planners can minimise costs, reduce environmental impact and maximise the use of resources [15].

Artificial intelligence and project scheduling

The findings indicate that AI has the potential to revolutionize project scheduling through dynamic, adaptive and predictive approaches. Other classic methods for scheduling are the critical path method, which assumes fixed activity sequences, fixed activity durations and are susceptible to disruption. AI-based scheduling models, on the other hand, can be continually updated with real-time data from the project itself, thus enhancing resilience and flexibility [16].

Genetic algorithms, reinforcement learning or mixed optimization models are frequently used to solve complex problems with resources constraints and uncertainty in scheduling. The approaches are shown to yield more efficient schedules, fewer resource conflicts and less idle time than the traditional approaches [17]. In addition, AI also assists in collaborative scheduling by amalgamating information from multiple project stakeholders and online platforms.

Artificial intelligence-based scheduling systems, together with building information modeling, offer greater insight into the project progress and dependencies [18].

Artificial intelligence and project control

According to the literature, artificial intelligence is strongly recommended to improve project control through real-time monitoring, anomaly detection and the management of predictable performance. The conventional project control relies on periodic reporting and retrospective analysis, which do not provide the opportunity to react in advance to emerging problems. Control systems based on artificial intelligence use real-time data streams to continuously evaluate project performance and predict the future [19]. The transformation from traditional project management practices to AI-driven project management is illustrated in **Figure 3**.

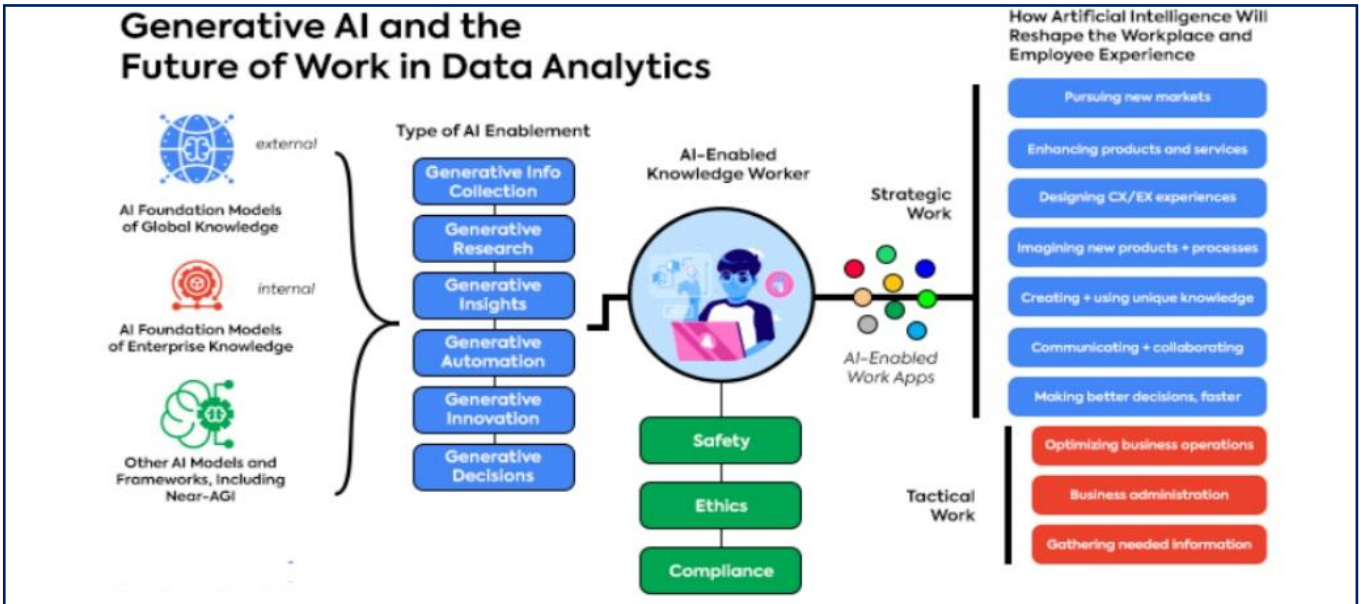

Figure 3: Transition from traditional to AI-driven project management.

Predicting cost overruns, schedule slippage and quality deviations based on prevailing project conditions is increasingly being done using machine learning models. These forecasting features enable project managers to take corrective measures before issues arise and to enhance project performance [20].

Although these are the advantages, the results also point to major disadvantages related to the application of artificial intelligence. One other critical constraint that immediately presents itself is the availability and quality of the data, with most organizations not having a data system in place that will support advanced analytics.

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Additionally, the technical knowledge and the change resistance of project staff do not contribute to the effective adoption [21].

Integrated Artificial Intelligence Project Management Framework (IAIPMF)

The results show that the use of artificial intelligence in engineering and construction project management is not limited to specific technological moves in project planning, scheduling or project control. Adaptive decision systems, organizational readiness, governance mechanisms and performance management practices are all increasing in importance for effective implementation and require coordination with the predictive analytics capabilities. This research proposes an Integrated Artificial Intelligence Project Management Framework (IAIPMF) for project planning, scheduling and control, based on the thematic synthesis. The first part of the framework is based on AI-based project planning such as cost estimation, project duration prediction, risk forecasting, scenario analysis and strategic decision support.

The second part is dedicated to adaptive scheduling systems, such as optimization algorithms, reinforcement learning models, dynamic scheduling, intelligent resource allocation and predictive delay management.

The third part focuses on intelligent project control, which involves real-time monitoring systems, anomaly detection, performance analysis, predictive control systems and early-warning systems. The fourth component is Organizational readiness and governance that includes leadership commitment, staff capability, data infrastructure, ethical governance, stakeholder trust and implementation readiness. The last component is integrated project performance outcomes, predictive accuracy, schedule flexibility, operational resilience, proactive decision making, project efficiency and project performance over time. The proposed framework provides a complete understanding of intelligent project management in complex engineering and construction, supported by AI technology.

Discussion

The results of the work confirm and expand on the previous research conducted on the role of AI in project management and they illustrate the beneficial effect of AI on project management. AI-driven operation planning, scheduling and control can put organizations beyond the traditional reactive way of operating to a proactive and data-driven approach. In the way the change is a paradigm change. Projects are planned and controlled, particularly in the complex building construction and engineering environment, that is uncertain and interdependent. The outcomes have demonstrated that AI can provide benefits for this project in area of accuracy and smart and foresight management. Monitoring and proactively analysing in real-time provides project managers with the opportunity to detect risks and opportunities early and take appropriate action to take the process further. This is aligned with the new concept of project management that is based on agility, resilience and learning practices [22]. The discussion indicates that having the technical skills is not enough for successful AI implementation. One of the organizational factors that is critical in determining outcomes of the implementation is leadership support. Berssaneti et al., point out that the project manager must acquire new skills to analyze data, apply systems thinking and make moral decisions to make use of the tools of artificial intelligence [23].

Ethical and Governance concerns are emerging as important topics of discussion, in particular the protection of data, the transparency of algorithms and the accountability thereof. As AI systems are increasingly involved in decisions that impact projects, it is essential that their use is done in a responsible and transparent manner, to build stakeholder trust. However, there is a need to find clear governance structures and ethical principles specific to project management situations, to overcome these problems. Overall, it is clear that AI is a promising and challenging trend in project management practice. The possibilities are huge, but they can only be achieved through an all-encompassing approach which combines the technological, the organisational and the human aspects. The study contributes to the ongoing discourse by presenting a synoptic perspective on the impact of AI on the fundamental project management processes as well as the context in which these impacts might be best harnessed.

Theoretically, the integrated artificial intelligence project management framework proposed in this paper marks a new direction in the field of project management, by incorporating technical, organizational, governance and performance aspects in a single conceptual framework.

The framework provides a blueprint for organizations pursuing the integration of AI into their operations, helping them ensure that AI enhances operational efficiency and sustainable project performance while maintaining decision-making capabilities and operational resilience. The findings also highlight the importance of organizational skills, ethical governance and data readiness in ensuring the effective implementation of AI-driven project management tools.

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Practical Implications

The research study offers valuable insights for practitioners on the promise of AI in improving project performance. An investment should be made in data infrastructure and developing interdisciplinary data teams, with project management and data analytics skills. Risks are minimised by engaging in pilot projects and gaining confidence in the use of artificial intelligence systems.

Theoretical Contributions

The aim of this study is to develop an Integrated Artificial Intelligence Project Management Framework that conceptualizes planning, scheduling and control as interconnected elements of intelligent project management systems to make a contribution to the project management theory. The framework brings together a unified analytical framework that goes beyond conventional project management concepts and introduces artificial intelligence tools, organizational preparedness, governance aspects and adaptive decision-making.

Conclusions

It seeks to make a broad study of the literature associated with the influence of Artificial Intelligence (AI) in the Engineering and Construction Management project planning, scheduling and control. The results indicate that AI can transform the conventional project management processes, providing a data-driven, flexible and proactive approach to decision-making. The main takeaway is that AI tools and processes can deal with uncertainty and complexity in projects and environments that traditional, deterministic methods cannot, such as through high-level forecasting and optimization tools, real-time monitoring and more. It states that AI is vital for improving the accuracy of planning, such as more precise cost, duration and risk estimates, flexible and resilient planning with dynamic updates and predictive modelling and continuously monitoring project performance and tracking early risks with project control.

Most importantly, the study reveals that the highest value of AI can be realised when planning, scheduling and control is more of a combination of an intelligent project management system than distinct individual processes. Though these advantages, however, it also indicates many potential obstacles which can hinder broad adoption: data issues of availability and quality, organizational issues of readiness, skill issues of personnel and ethical issues of transparency and accountability. These challenges can be overcome by investing in technology and committed resources of leadership, governance mechanisms and capacity building. Overall, this study contributes both theoretically and practically to the field of project management using AI, providing a holistic view of the use of AI in project management and the conditions for successful implementation.

As part of the fast pace of digitalization, AI should be the key to improving the performance and resilience of complex engineering and construction projects. This study theoretically develops into the Integrated Artificial Intelligence Project Management Framework and methodologically through the structured thematic synthesis of the latest literature on the application of AI in project management. The results provide a foundation for conducting more research on intelligent project systems, intelligent governance of AI, adaptive scheduling environments and data-driven engineering project management.

Limitations and Future Research

The secondary data that is available in the literature is the limitation in this research. The empirical studies and longitudinal studies should be included in future research to confirm the findings. Further studies on the ethical, legal and social aspects of artificial intelligence on project management are also warranted.

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