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A Review of the Application of Decision Tree Analysis and Artificial Neural Networks in Project Management

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ABSTRACT

The advancement of computing and communication technologies has fueled the growth of Information Technology (IT), with Artificial Intelligence (AI) emerging as a transformative force in modernizing project management practices. This study explores the application of two prominent AI techniques—Decision Tree Analysis (DTA) and Artificial Neural Networks (ANN)—in improving project planning and control. A review of empirical studies highlights the limitations of conventional tools such as Gantt charts and the Critical Path Method (CPM) in managing complex project variables, often resulting in cost overruns and schedule delays. In contrast, DTA and ANN demonstrate superior predictive accuracy, decision support, and adaptability capabilities. DTA offers transparent and structured decision-making models, while ANN excels in pattern recognition and outcome forecasting. The findings underscore that integrating these AI tools enhances project efficiency, cost estimation, and time management, establishing AI as a critical asset for future project success.

Keywords: *Artificial Intelligence, Decision Tree Analysis, Artificial Neural Networks, Project Planning, Project Control*

Introduction

Decision Tree Analysis (DTA) and Artificial Neural Network (ANN) which have found their application in project management in areas such as: organizational effectiveness; cost and budget performance; tender bids; cash flow; construction demand; labour productivity; earth moving operations; prediction of cost and project duration [1]. During failing projects, there is potential for data mining in the project management discipline to increase project success rates; Estimation (effort, duration, quality, and cost). A major research area in machine learning is classification, a supervised learning method. In a classification problem, each item is defined by attribute values and a label to predict the target class label. Decision trees are analytical tools that solve regression problems. Decision tree techniques have been widely used to build classification models closely related to human reasoning and are easy to identify with [2], [3]. Decision Tree Analysis (DTA) in project management can be achieved with a diagram that assists in decision making for the successful implementation of a project. Decision trees can be employed to create a Best-First Decision Tree (BFT), a Bagging Best-First Decision Tree (BBFT) ensemble, and a Dagging Best-First Decision Tree (DBFT) ensemble to spatially predict the probability of occurrence of an event[4]. Gradient Boosting Decision Trees (GBDTs) have also become very successful for machine learning and data mining. The decision tree machine learning approach can significantly improve predictive accuracy [5]. The progression towards AI is in the context of the followings: Expert system in the 80s which was rule-based for businesses, reasoning system in the 90s such as the deep blue AI chess that dethroned Kasparov, perception tasks in the 2000s which includes speech recognition and image recognition and currently reasoning and perception are being connected. Artificial intelligence comprises sixteen categories: reasoning, data mining, expert systems, knowledge representation, machine learning, fuzzy logic, genetic algorithms, and neural networks [6]–[9]. Fuzzy logic is a component of AI, and it is mainly used to solve non-linear problems [5], [10], [11]. Fuzzy logic can be applied to decision-making and the evaluation of

efficiency in projects [12]. Though FL systems are understandable, they are not always accurate. Genetic Algorithm (GA) is a population-based stochastic algorithm. The standard components of GA are crossover, mutation, and selection [13][14]. Genetic Algorithm applied to project scheduling with limited resources (RCPSP) to improve resource allocation in project management.

Genetic Algorithm is easy to understand and can be applied to a population point. [15]–[18]. However, repetition of fitness function evaluation is limited and computationally time-consuming. Artificial Neural Network (ANN) is a computational model based on the composition of a biological neural network. Artificial Intelligence is an important area of research in all fields today. [19]. Artificial Intelligence (AI) has developed so that tracking studies have become complex. [20]. AI studies have been distributed into almost all fields, with each area becoming an individual field of knowledge.[21]–[23]. There are many debates regarding AI, including: Artificial intelligence or artificial life? How do we get AI to have common sense that we take for granted? Who is in control (human or machine)? What will happen if AI threatens us? Will AI kill us? What are the effects of a system attack? Will AI develop an emotional response to inhuman actions? Who is in control? [24], [25]. The application of AI in project management has improved decision-making and project performance. [26]–[30]. The predictive capability of project variables has been implemented based on expert judgments and the knowledge of project stakeholders. Studies make project management models to identify risks and their effects on projects.[31]. Artificial Intelligence is set to modernize project management, making it more modern, predictive, and automated than ever. If appropriately coded, intelligence has higher accuracy and precision and can complete dangerous activities than humans. [32].

Projects are bounded by uncertainties and changes, creating challenges for efficient project planning and control. [33]. Traditional methods are limited in modeling and predicting project variables. [34]Problems with project time and cost overruns affect the quality and scope of most projects. [35]–[43] Organizations face high project failure rates, and recovering a failing project is often expensive, which may lead to its abandonment. [44]These failures result from a lack of personnel, resources, hardware, and asset improvement, and unreliable regulations and standards for building operations. [45]. Past studies have focused on Nigeria's traditional project planning and control techniques, such as the critical path method (CPM). A CPM analysis is traditionally scheduled on unlimited resources. However, an efficient scheduling process must consider the constraint of limited resources and evaluate resource allocation and leveling required to prevent project variations. [46]. Poor resource planning results in shortages and delays. The plan must include a specific schedule informing stakeholders of the necessary resources and actions. Failure to plan will reduce the productivity and performance of any organization. [47].

Poor project planning and control implications lead to poor project quality, which affects a nation's or organization's life and economy. Considering the large size and complexity of today’s projects, there is a need for an improved framework for project planning and control to identify and predict critical success factors to establish project success. Suppose the problem of poor project planning and control is resolved. In that case, it will lead to the following: Improved project planning and control, identifying and predicting critical factors of project success, optimizing project cost and time, and providing a knowledge base for developing nations.[48]–[50] Artificial Neural Networks are a component of AI, and their technology is fascinating. AI and its components can gather the data needed to monitor projects. [51]. Artificial Intelligence emulates the potential of human cognition, and it consists of techniques to allow project managers to perform their tasks accurately and efficiently. [52]. The target beneficiaries include project stakeholders, expert system developers, decision makers, and the general populace. It is to be noted that AI will not replace the human mind, and machines need humans to operate. [53].

[54] Highlighted that project plans are documented in the project planning phase. Requirements and deliverables are established, and the schedule is designed. The plan guides the team throughout the project life cycle. Project planning is at the heart of the project life cycle and schedules tasks for team members and stakeholders in general, as shown in Figure 1 [55], [56].

Research Method

The project planning phase is the most tasking phase for a project manager. The project manager must know the project team, communications, procurement activities, resources, equipment, contract, and third-party suppliers. Project planning aims to establish business requirements, project cost, resources, scheduling, deliverables, and project delivery time. [54]Project planning techniques

include a Work Breakdown Structure (WBS), a Gantt chart, and a Program Evaluation and Review Technique (PERT). A WBS is used to break down the project into tasks. A Gantt chart is a horizontal bar chart showing activities against their respective durations. Program Evaluation and Review Technique (PERT) charts put the functions into sequence, and Gantt charts are horizontal bar charts, with each bar representing the duration of a task.

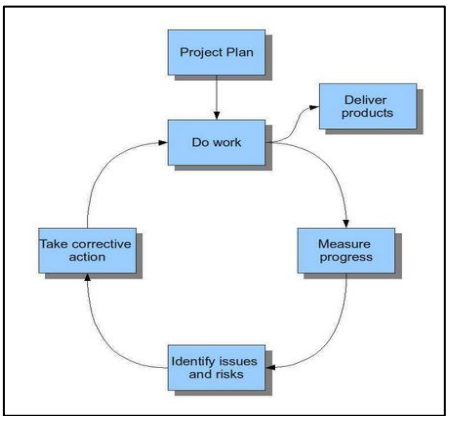

Figure 1. Project planning life cycle

[57] Evaluated methods for decision-making in project planning and control. The authors reviewed recent tools developed for project planning and control. Decision-making problems were project scheduling, resource allocation, and cost evaluation. Results show a growing attention to the stochastic nature of projects in decision making. This study highlighted that considerations were made regarding existing techniques and automated methods. Project Monitoring plays a vital part in project planning and control. Project Monitoring is the process of tracking and controlling project metrics. [58]The project monitoring process identifies challenges and actions required to meet the project scope, budget, and duration. It monitors the implementation tasks as planned and provides a guideline for a project manager's decision-making processes. Project monitoring commences at the planning phase and measures project goals using Key Performance Indicators (KPIs).

Project Monitoring can also be attained through project stakeholders' weekly, monthly, or annual meetings, retreats, and progress reports. Others are project parameter monitoring, such as costing and timeline, stakeholders' commitments, project risks, process, people, technology, tools, and inventory monitoring. Monitoring reports are required and developed. Finally, the plan for project closure must be monitored. Corrective actions are needed to control the project plan if the project is not on track. [59]. The theories examined in this study are Critical Path Method (CPM), Resource Constrained Project Scheduling Problem (RCPSP), Decision Tree Analysis (DTA), Artificial Neural Network (ANN), Artificial Intelligence (AI), Machine Learning, and Matrix Laboratory (MATLAB). This study adopts the random forest decision tree algorithm for decision analysis and the feed-forward back-propagation neural network algorithm for computational and predictive analysis. These algorithms are subject to an AI framework that aims to improve project planning and control. Project scheduling is optimizing project activities, materials, and resource allocation. The duration of each activity is analyzed, and communications are accurately established among project stakeholders. [60].

Scheduling techniques include Gantt Charts. A Gantt chart offers an outline of a project and provides descriptions of tasks and their timelines. It mainly shows completed tasks, delayed tasks, resources, and milestones. Program Evaluation and Review Technique (PERT)—The PERT analyzes a large project as a series of activities. Critical Path Method (CPM)—The CPM is a famous scheduling tool for calculating project timelines. The RCPSP takes into consideration the availability of limited resources and activities. The problem is to design an optimal schedule by assigning a timeline to each activity and considering the availability of required resources. The heuristic method is reaching the optimal schedule solution by following basic rules. The heuristic method employs two simple concepts. These concepts are the reduction of project time and the reduction of project cost. [61]. Resource overloading is the poor estimation and allocation of resources. Tasks and activities are to be prioritized, and higher priority tasks are allocated resources from the limited resource pool. A lack of resources may also result in resource overloading.

Scheduling issues or resource overloading can be identified and resolved by applying these steps:

i. Prepare an efficient schedule that shows tasks and their resource requirements.

ii. Develop a chart that outlines resource requirements for a high-priority and early-start schedule.
iii. Fine-tune the project schedule within the resource constraints.

In a situation where the project duration is too long with limited resources and the project cannot be outsourced, control options are:

i. Reduce undue functionality and project scope.
ii. Accept the current milestone.
iii. Accelerate critical tasks by working overtime or adopting improved project management tools.
iv. Split or eliminate tasks to fit the resource allocation outline
v. Remove task dependencies to achieve scheduling flexibility.

Project management software can level resources automatically. However, it may also be required that tasks are delayed until resources are provided. Resource smoothing is applied to tasks not on the critical path, while resource leveling is not restricted.

Result and Discussion

Brain Neurons

The brain is a human organ that controls the entire body. Brain functions include thinking, visualizing, dreaming, imagining, and learning. The neuron is a specialized cell designed to transmit information to other cells. [62]. The interconnection of neurons makes up the brain and neural network. The brain is made of cells called neurons. The neuron is the working unit of the brain. There are about 1,011 neurons in the human brain. A natural brain can learn and adapt. Biological neurons comprise a cell body, an axon, and a dendrite. The cell body contains the nucleus and chemical structures. Axon carries signals between neurons. Dendrite receives electrochemical signals from neurons into the cell body. Synapse connects dendrites of two neurons, or a neuron to muscle cells. Artificial Neural Network was designed to function and mimic the human brain neuron. [63].

Artificial Neural Network (ANN)

Artificial Neural Networks (ANNs) attempt to simulate human thinking for prediction purposes. They are more accurate than linear models. ANNs are applied to detect Critical Success Factors (CSFs) in projects. Figure 2 shows the generic architecture of ANNs [64].

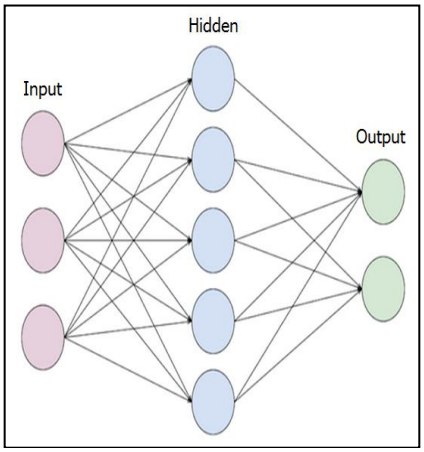

Figure 2. Generic Architecture of ANNs

Artificial Neural Networks, also termed Neural Networks (NNs), are specific modeling techniques capable of representing complex relations. It requires the collection of data that will sufficiently represent the sample population. ANN belongs to the family of AI [65]. Artificial Neural Networks have the following building blocks: Neurodes- An artificial model of the biological neurons; Interconnects- these are paths or links between neurodes and the artificial model of the biological axons; Synapses – These are junctions where an interconnect meets a neurode. The advantages of neural networks are as follows: They have self-learning capability; they apply to simple, complex, linear, and non-linear problems; they require no prior knowledge of data relationships; they have self-tuning capability. The disadvantages of ANN are as follows: It cannot manage vague and imprecise

information; It cannot handle linguistic information; It cannot combine numeric data with linguistic or logical data; It relies on trial-and-error process to determine hidden layers and nodes of a universe of discourse; It cannot resolve information conflicts by collaboration, propagation and aggregation. Neural network applications are classified under supervised and unsupervised learning, classification, regression, pattern recognition, and clustering. The learning dataset contains input and system output signals in supervised learning. Network learning is a process of network reaction to a stimulus done with precision. Supervised neural networks are trained to produce target outputs in response to sample inputs. They are suited for modeling and controlling dynamic systems and predicting and classifying noisy data. Pattern recognition classifies input data based on key features, by employing supervised or unsupervised classification. It is applied to speech recognition, text classification, computer vision, and radar processing. Supervised pattern recognition techniques are used for optical character recognition, face recognition, object detection, and object classification. Classification is a technique in supervised machine learning for classifying observations from labeled data. Regression models illustrate the relationship between output variables and input variables. Unsupervised learning is providing input data to a machine learning algorithm without information about the output signal. The algorithm analyzes the relations among the input data itself. Unsupervised ANNs are trained by continuous adjustment of inputs. They are used to draw inferences from data sets consisting of input data without labeled outputs. Clustering is the grouping of data based on similar features. It is a form of unsupervised learning. Cluster analysis is applied to gene sequence analysis, recognition of objects, and market research. Figure 3 shows the relationship between Machine Language and Neural Network.

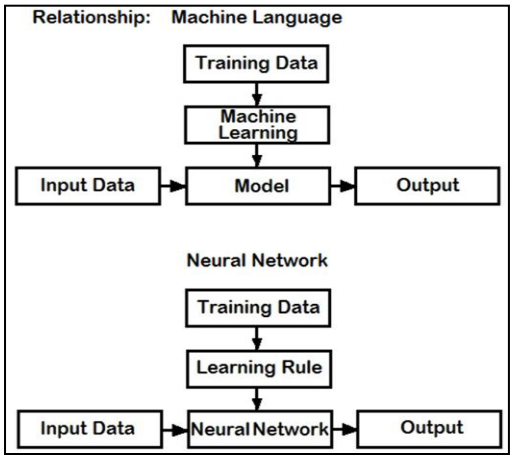

Figure 3. Relationship between Machine Language and Neural Network

ANN Terminologies

Terminologies such as epochs, batch size, and iterations are required when the data is large. To overcome this, data is divided into smaller sizes and provided for learning. [66]. One epoch is achieved when a dataset batch is fed forward and backward through the neural network once. One epoch may be too large to be fed to the computer simultaneously, dividing it into several smaller batches. As the number of epochs increases, the weights are changed more times in the neural network. The batch size is the number of training samples in a single batch. The entire dataset may be too large to be fed into a neural network simultaneously, so it is divided into batches or sets. The number of batches equals the number of iterations for one epoch.

Data Mining and Knowledge Engineering and Sources of Data

Data mining involves accessing databases to generate new information. Knowledge engineering is the branch of AI concerned with building knowledge-based systems. [67]. Machine Data Sources: (Smart Devices, Sensors, Medical Equipment). Machine Data characteristics: (Extensive, Tabular, Detailed, and can be connected). Organization Data Sources: (Government Agencies, Project Organizations, Financial Institutions, Hospitals, Retail Stores). Characteristics of Organizational Data: (Structured, in silos, Variability).

People data Sources: (Facebook, Twitter, Instagram, YouTube). Characteristics of people Data: (Huge, 80% of World Data, Fragmented, unstructured, and Variability).

The four levels of knowing are data, information, knowledge, and wisdom. There is often a lack of understanding of the distinction between information and knowledge and between explicit and tacit knowledge. Data are the pure and simple facts without structure or organization and are referred to as the basic atoms of information. Information is structured data, which adds meaning to the data and gives it context and significance. Knowledge is the ability to utilize information to achieve a goal strategically. Finally, wisdom is choosing objectives consistent with desired values within a larger social context. Figure 4 shows the evolution of data. Data with context becomes information, information and meaning become knowledge, knowledge and insight become wisdom.

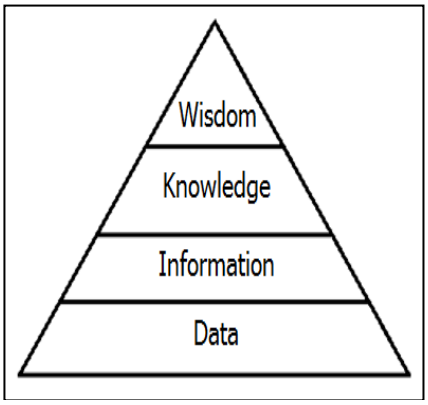

Figure 4. Evolution of data

Machine Learning (ML)

Machine learning is a division of AI. It adopts techniques to allow systems to learn from data without human intervention. Machine learning allows systems to understand the natural environment and adjust accordingly. [68][69] .Examples of some machine learning-powered project management applications are: Forecast—Forecast uses AI to automate resource and project management in digital agencies. It creates regression models by learning from project history. Knightspear - Knightspear is an information technology project management tool. It has a virtual assistant chatbot called Isabella to assist project managers in decision-making. She is interactive and makes users feel more engaged. KnightSpear augments Isabella's machine learning capability to provide a better and smarter AI work coach for project management. The information required for project monitoring is available to project managers and teams. This reduces time spent on gathering and interpreting data. It also provides more time for taking action. Isabella is an AI-enabled chat-box work coach. Isabella helps with project monitoring in the following ways: provides recommendations and suggestions, ensures that recommended actions are implemented, monitors team performance in real-time, and provides regular status and progress reports. Teodesk - Teodesk is based on natural language processing. It can automatically assign emails for organized information dissemination.

Lili automates recurring tasks such as meeting schedules. It identifies risks and proposes tasks to minimize their impact. It helps prioritize to-do lists to save time and emails weekly progress reports. Autodesk BIM360 IO - Autodesk BIM360 IO is used for project design, scheduling, cost estimation, safety, and maintenance processes. [70].

Machine Learning denotes a program's ability to learn, while AI encompasses learning along with other functions. Deep Learning (DL) is part of a family of machine learning based on data representations. Deep Learning networks have many layers compared to the fewer ones in shallow learning. Artificial Neural Networks and DL are ML techniques. [71].

[10] Carried out a study on the applications of Fuzzy Logic. The authors stated that Fuzzy logic is a component of AI and has a solution for nonlinear problems. Due to its predictive capabilities, fuzzy expert systems have many applications in project management. Though FL systems are understandable, they are not always accurate. Today's projects are complex and require more analysis for efficient decision making and planning.

[12] examined the application of fuzzy logic to decision making and evaluation of project management. Project cost, time, and quality were the variables considered in the study. The approach employed fuzzy decision making (FDM) to combine these variables and present them as project management internal efficiency (PMIE). A case study was used to evaluate the adapted method. The decision-making system was implemented with MATLAB software. Results showed that PMIE indicates the project objectives' achievement level and evaluates project teams' performance. Project

cost, project time, and project quality require reliable information for analysis. Fuzzy Logic (FL) may not offer accurate reasoning, but it is acceptable for providing a solution to some complex issues. Fuzzy decision making accepts assumptions that can reduce the accuracy of evaluation results. These systems lack the capability of machine learning neural networks. The validation of a fuzzy knowledge base is extensive

[15] Applied Genetic Algorithm (GA) to project scheduling with limited resources. The study presented a GA for the Resource-Constrained Project Scheduling Problem (RCPSP). The study provided a multi-array object-oriented model for the representation of the chromosome. The model utilized programming features for decision support systems. The approach was tested with sets of standard problems on the Internet. Results show that the approach is in tandem with previous methods. Genetic algorithms are easy to understand and can be applied to a population. However, repetition of fitness function evaluation is limited and computationally time-consuming.

[16] Examined the resource allocation in extensive construction project management using GA. Large projects require many resources, and there is a need to utilize limited resources effectively. This paper analyzes existing problems of resource allocation and resource leveling. The optimization model based on GA was given and compared with traditional methods. The performance of the GA model was better when considering project time. The application of GA provided a solution for resource allocation optimization. However, designing the objective function and getting the representations right with GA is difficult and still an art.

[17] Examined resource allocation and presented a resource-driven project scheduling model using GA. Project complexity increases due to the increasing number of activities, resource types, and execution modes. The typical integration of alternative activity execution modes, known in template form, was not supported. The multi-objective approach evaluated resource duration alternatives and aims at reducing total cost. The algorithm was tested, and the results were compared to those of Microsoft Project. The GA provided a balanced solution concerning the three objectives. The results of the study were tested using only Microsoft Project. There are numerous project management software tools in the market. A Genetic Algorithm alone cannot provide a precise solution to the cost overrun issue. They developed a GA-based adaptive project for human resource management. The GA method was adapted to arrange workers according to assignment and control workload. A project management problem that evaluates congestion by job arrival ratio in an operation was selected and simulated. The GA model shows superior qualities when compared with the Dijkstra method. Genetic algorithm performs well with discrete and continuous problems.

[72] Examined neural networks with decision trees in the application of wine classification. The model adopted in this paper shows neural network training preceding the decision tree. The model was evaluated in terms of accuracy, comprehensibility, and fidelity. Neural networks were first trained and then combined with decision trees. Neural networks classified data from Italian wines in a region with three different wine cultivars. Knowledge was extracted from the trained network using J48 decision trees. Decision trees were also used to train on the same dataset, and their performance was compared with that of neural networks. Neural networks perform better when compared to decision trees in the classification of wines. However, extracting knowledge from neural networks did not perform better than decision trees. The authors stated that there are arguments for why neural networks are insufficient for data mining due to their inability to explain system functionalities clearly for users to understand. Results on three datasets show that the algorithm generated reliable rules.

[73] Examined and evaluated an ANN model for predicting the duration of projects. The study identified the main factors affecting the project duration of construction projects in India. Eighty-four factors were identified: project location, project design complexity, equipment shortage, material shortage, and project location. The ANN model aimed to predict the duration of ongoing projects in conjunction with conventional techniques. A large number of iterations were carried out. The ANN results were compared with conventional techniques, and the ANN model's variance had the best performance, making the ANN effective for predicting project duration. It was concluded that the ANN-predicted project duration can improve the project's planning process and reduce cost overrun.
Table 1 shows features of DTA and ANN.

Table 1. Summary and Features of ANN and DTA

S/N	Features	DTA	ANN
1.	Self-Explanatory Ability	Yes	No
2.	Computational Speed	Faster	Fast
3.	Accuracy	Less	More
4.	Knowledge Extension	Itself	Require other methods

5.	Complexity	Moderate	High
6.	Performance	Moderate	High
7.	Need for Test Cases	Few	Many
8.	Problem Domain	Less Complex	Complex

Discussions

The performance of project success based on existing perspectives and principles was not accurate for predicting project time and cost. Empirical review revealed that DTA and ANN can achieve the followings in comparison with the existing techniques: Evaluate and estimate project cost; determine the duration of a project; Describe systems in both numeric and symbolic terms makes it more versatile in comparison with others; Shorter development time than traditional methods; Project selection to determine the most sustainable project; Creation of system models; Collaboration with other methods and techniques; Efficient for the analysis of vague and infinite data; Prediction of project deliverable values and estimation of project success value.

Conclusion

Preliminary reviews show that past studies are primarily focused on traditional project planning and control techniques in Nigeria, which were based on WBS, Gantt chart, PERT chart, and CPM. Having observed the traditional approaches to project planning and control and the cost and time overrun levels in many projects, it was essential to provide an alternative approach driven by AI. Artificial Intelligence components are fascinating and force us to rethink everything we know about project management. Artificial Intelligence algorithms are modelled to learn from past experiences like humans. The hybridization of AI components provides optimal project planning and control performance. Therefore, AI techniques should be prioritized during project planning and control. The study provides reliable information on the benefits of AI tools to project stakeholders and policymakers for efficient project management.

This study was carefully prepared and provided reliable information on advancing AI tools for successful project management. However, more studies are required on the limitations of AI-driven project management systems, including their effect on people and the environment.

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