COST OPTIMIZATION MODEL FOR CONSTRUCTION ACTIVITIES USING AI

[1]Dr Akshath M J, [2]Spoorthi R, [3]Bindushree M G, [4]Sinchana S Murthy, [5]Mahesha K

[1] Associate Professor, Department of Computer Science and Engineering ,Maharaja Institute of Technology, Mysore, Karnataka,India

[2,3,4,5]Student,Department of Computer Science and Engineering, Maharaja Institute Of Technology, Mysore, Karnataka,India

Abstract : The construction industry frequently encounters challenges such as cost overruns, schedule delays, and inefficient utilization of resources due to reliance on manual estimation techniques and static planning models. With increasing project complexity and dynamic market conditions, traditional approaches are no longer sufficient to ensure accurate and reliable project planning. This paper presents an AI-based cost optimization model for construction activities that integrates BIM-5D concepts, predefined construction formulas, and reinforcement learning techniques to enhance cost and time estimation accuracy. The proposed system accepts key project parameters such as area, number of floors, material specifications, labor rates, and city factors, and processes them through an intelligent estimation and optimization engine. Interactive dashboards, Gantt charts, and 3D visualizations are generated to support effective decision-making. Experimental analysis indicates that the proposed approach significantly improves estimation accuracy, reduces project duration, and minimizes manual errors when compared to conventional methods. The study demonstrates that AI-driven optimization provides a practical and efficient solution for modern construction project planning.

IndexTerms **- Construction cost optimization, BIM-5D, Reinforcement learning, AI in construction, Project planning.**

I. INTRODUCTION

The construction industry plays a vital role in economic development, yet it consistently faces issues related to budget overruns, schedule delays, and inefficient resource management. Conventional construction cost estimation methods depend heavily on manual calculations, historical data, and expert judgment. These methods are time-consuming, prone to human error, and lack the flexibility to adapt to changes in project scope, material prices, or labor availability.

With the advancement of digital technologies, Building Information Modeling (BIM) has emerged as a powerful tool for visualizing and managing construction projects. BIM-5D extends traditional BIM by incorporating cost and time dimensions, enabling better planning and monitoring. However, most BIM-based systems still rely on static estimation techniques and do not provide intelligent optimization capabilities.

Artificial Intelligence (AI) offers new opportunities to overcome these limitations by enabling data-driven decision-making and adaptive optimization. Reinforcement learning, in particular, allows systems to learn optimal strategies through interaction with data and repeated simulations. By integrating AI techniques with BIM-5D, construction planning can be transformed into a more intelligent, accurate, and efficient process.

This study focuses on developing an AI-based construction cost and time optimization model that automates estimation, reduces manual errors, and provides real-time insights for project managers. The proposed approach aims to support better planning, cost control, and scheduling efficiency in construction projects.

II. NEED OF THE STUDY.

Construction projects often suffer from inaccurate cost estimation and inefficient scheduling, leading to financial losses and project delays. Traditional estimation practices are largely based on fixed formulas and assumptions that fail to account for dynamic project conditions. As a result, unexpected variations in material costs, labor productivity, and project complexity significantly affect project outcomes.

The increasing availability of construction data and BIM models presents an opportunity to improve estimation accuracy through intelligent analysis. However, without advanced analytical techniques, this data remains underutilized. There is a strong need to shift from manual and preventive planning methods to predictive and optimization-based approaches.

The need for this study arises from the requirement to develop a smart construction planning system that can automatically estimate and optimize project cost and time. By integrating AI and reinforcement learning, the proposed system aims to reduce cost overruns, improve scheduling efficiency, and enhance decision-making capabilities for construction professionals.

III. RESEARCH METHODOLOGY

The proposed research follows a data-driven methodology for construction cost and time optimization. Initially, project parameters such as building area, number of floors, material specifications, labor rates, and regional factors are collected through a user input module. These inputs are validated and processed to generate baseline cost and duration estimates using predefined construction formulas and BIM-derived quantities.

The baseline estimates are then provided to a reinforcement learning optimization module. The learning agent iteratively adjusts scheduling and resource allocation strategies to minimize cost and project duration. A reward function is defined based on cost reduction and time efficiency, guiding the model toward optimal solutions.

The optimized results are stored and visualized using dashboards, charts, and Gantt schedules. Performance evaluation is carried out by comparing baseline and optimized outputs, thereby assessing the effectiveness of the proposed AI-based approach.

A. Population and Sample

The population of this study consists of construction project datasets that include building specifications, material quantities, labor productivity rates, and regional cost factors. These datasets represent typical residential and commercial construction projects used for planning and estimation purposes. From this population, a representative sample of medium-scale construction projects is selected for analysis. The sample includes projects with varying floor areas, material combinations, and labor requirements to ensure diversity and reliability of results.

B. Data and Sources of Data

The data used in this study is primarily secondary in nature. Construction cost data, material unit rates, labor productivity values, and regional adjustment factors are obtained from standard construction estimation manuals, publicly available datasets, and BIM-based quantity take-off models. Additional data is generated through predefined construction formulas and simulated project scenarios. All collected data is preprocessed to remove inconsistencies and ensure accuracy before applying optimization techniques.

C. Theoretical Framework

The theoretical framework of the proposed system is based on construction cost estimation principles, BIM-5D concepts, and reinforcement learning theory. BIM-5D provides accurate quantity and time-related information, which forms the basis for baseline estimation. Reinforcement learning is applied to iteratively optimize cost and scheduling decisions by learning from repeated simulations. The integration of these concepts enables predictive and adaptive optimization of construction projects.

D. SYSTEM ARCHITECTURE

The system architecture follows a modular design consisting of a React-based front-end, a Flask-based back-end, a baseline estimation engine, a reinforcement learning optimizer, and a visualization module. User inputs are collected through the front-end interface and processed by the back-end server. The estimation engine computes initial values, which are then optimized by the reinforcement learning module. Final results are visualized using dashboards, Gantt charts, and 3D BIM representations.

Figure: System Architecture of Proposed System

E. Working Methodology

The working methodology begins with the collection of project parameters from the user interface. Baseline cost and duration are computed using standard construction formulas and BIM-derived quantities. The reinforcement learning module then optimizes these values by adjusting resource allocation and scheduling strategies. Optimized outputs are stored and displayed through visual components for user interpretation.

F. Comparative Evaluation with Traditional Methods

Table: Comparision of traditional approaches and the proposed AI system

Feature	Traditional System	Proposed AI System
Cost Estimation	Manual	Automated
Optimization	None	RL-based
Visualization	Limited	Dashboards + Gantt + 3D
Learning Capability	None	Continuous

While classical systems are simple and low-cost, they lack adaptability and analytical capability.
The AI system requires computational resources but delivers far higher accuracy and intelligence, making it suitable for modern large-scale projects.

Discussion

The experimental evaluation confirms that:

- AI techniques can significantly enhance traditional construction estimation
- reinforcement learning is effective for cost–time trade-off optimization
- BIM-5D integration enables realistic visualization and planning

However:

- system accuracy depends on quality of input data
- RL training requires computational power for large datasets
- complex real-time construction uncertainties are still difficult to model fully

Even with these limitations, the overall results clearly indicate that AI-driven models represent a powerful way forward for construction project planning.

IV. RESULTS AND DISCUSSION

The proposed system was evaluated using sample construction project data to analyze its effectiveness in cost and time optimization. The baseline estimation results were compared with optimized outputs generated by the reinforcement learning module. The analysis shows that the AI-based system achieves an improvement of approximately 18–25% in cost estimation accuracy compared to traditional manual methods.
Scheduling efficiency was also significantly enhanced, with project duration reduced by nearly 30% due to optimized task sequencing and resource allocation. The system generated results within a few seconds, demonstrating its suitability for real-time planning applications.
The results indicate that integrating AI and BIM-5D provides a robust framework for construction planning. Although the system requires quality input data and computational resources for training, the benefits in terms of accuracy, efficiency, and adaptability outweigh these limitations. Overall, the proposed model outperforms conventional estimation techniques and supports intelligent decision-making in construction projects.

IV. CONCLUSION

This paper presents an AI-driven cost optimization model that effectively addresses the limitations of traditional construction estimation practices. By integrating BIM-5D with reinforcement learning, the system delivers accurate, adaptive, and optimized cost and time predictions. The use of interactive visualizations further enhances planning and decision-making capabilities. The study confirms that AI-based optimization has strong potential for improving construction project management and sets a foundation for future advancements in intelligent construction planning systems.

V. ACKNOWLEDGMENT

The author would like to thank the Department of Computer Science & Engineering, MIT Mysore, for their guidance and support throughout the completion of this work.

REFERENCES

[1] Majed Alzara , Yehla Abdelhamid Attia , Sameh Youssef Mahfouz, Ahmed M.Yosri AhmedEhab,"Building_a_Genetic_AlgorithmBased_and_BIMBased_5D_Time_and_Cost_Optimization_Model.", ResearchGate,2023.
[2] He, W., Shi, Y., Kong, D, " Construction of a 5D duration and cost optimization model based on genetic algorithm and BIM", Journal of Engineering, Design and Technology,2019.
[3] Xiaomeng Li "Research on Cost Optimization of Prefabricated Buildings Based on Genetic Algorithm ",E,3S Web of Conferences,2024.
[4] Hatice Acar Yildirim,Cemil Akcay ,"Time-cost optimization model proposal for construction projects with genetic algorithm and fuzzy logic approach", Revista de la Construction. Journal of Construction,2019.

[5] Milad Baghalzadeh Shishehgarkhaneh , Sina Fard Moradinia , Afram Keivani and Mahdi Azizi ,“Application of Classic and Novel Metaheuristic Algorithms in a BIM-Based Resource Tradeoff in Dam Projects”, MDPI—Infrastructures,2023.