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AI-Driven Project Management for Construction SMEs: A Framework for Cost and Schedule Optimization

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Abstract: Efficient project management remains a persistent challenge for small and medium-sized enterprises (SMEs) in the U.S. construction industry, where delays and budget overruns are prevalent. This study proposes an AI-driven project management framework tailored to SMEs, integrating predictive scheduling, resource allocation, and real-time progress monitoring. By leveraging machine learning models and cloud-based visualization tools, the framework generates adaptive schedules and optimizes task prioritization. A case study using representative project data demonstrates that the AI-enhanced system reduces schedule variance and cost deviation compared to traditional critical path methods. Results indicate that SMEs can achieve significant improvements in project predictability and resource efficiency without incurring the high costs of enterprise-level tools. The proposed framework contributes to national priorities in infrastructure development by enabling SMEs—who comprise the majority of U.S. construction firms—to deliver projects with greater timeliness, cost-efficiency, and resilience.

Keywords: AI-driven project management; predictive scheduling; resource allocation; construction SMEs; engineering optimization

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1. Introduction

Small and medium-sized enterprises (SMEs) play a critical role in the U.S. construction industry. According to the U.S. Census Bureau, SMEs account for approximately 80% of all construction firms, undertaking a substantial portion of residential, commercial, and public infrastructure projects. These enterprises not only provide significant local employment opportunities but also contribute to community development and infrastructure renewal. Despite their prevalence, SMEs typically face limitations in resources, capital, technical capabilities, and information management. Consequently, they are more susceptible to challenges such as schedule delays, budget overruns, and quality control issues when managing complex construction projects.

Currently, many firms rely on traditional project management tools to plan and monitor project progress. Primavera P6 offers comprehensive scheduling and progress management features; however, its complex interface, extensive data input requirements, and high licensing costs make it difficult for SMEs to adopt fully. BIM360, on the other hand, excels in design collaboration and document management but provides limited support for predictive analytics and dynamic scheduling, making it challenging to deliver real-time, intelligent decision support. Moreover, many SMEs still rely on Excel for cost management, which creates data silos and makes it difficult to communicate schedule changes across platforms. Change orders, a common occurrence in construction, are also hard to capture accurately in cost forecasts, further reducing planning reliability. These tools often lack proactive mechanisms to anticipate schedule delays and resource conflicts, requiring frequent manual intervention from project managers. For SMEs without dedicated scheduling teams, these technological, data integration, and cost barriers significantly reduce management efficiency and project success rates [1].

To address these challenges, this study proposes an AI-driven project management framework tailored for small and medium-sized construction enterprises. The framework leverages machine learning and cloud-based technologies to enhance project management efficiency through:

Schedule prediction: Historical project data and real-time construction logs are consolidated across platforms to train predictive models for early detection of potential delays.

Task prioritization: Critical path analysis is integrated with intelligent algorithms to dynamically adjust task execution sequences, ensuring that schedule changes are automatically reflected in cost forecasts and resource plans.

Resource allocation: Smart scheduling algorithms optimize the utilization of labor, equipment, and materials by drawing on data from both cost management and scheduling systems, reducing inefficiencies caused by fragmented workflows.

Visual analytics: Unified dashboards powered by tools such as Power BI integrate schedule, cost, and risk data into one view. This allows project managers to see how schedule changes directly impact cost forecasts and risk exposure, providing a clear, real-time basis for proactive decision-making.

This framework not only lowers the adoption barrier for SMEs but also maintains compatibility with existing project management software, allowing firms to gradually integrate AI capabilities while preserving their current workflows. By implementing this framework, SMEs are expected to reduce manual intervention, improve schedule prediction accuracy, and mitigate cost overruns, ultimately enhancing overall project success rates.

In summary, the contributions of this study are twofold:

The development of a cost-effective, scalable, and intelligent project management framework specifically designed to meet the practical needs of SMEs;

The exploration of AI applications in construction project management, offering new avenues for productivity improvement and supporting the advancement of U.S. infrastructure development [2].

2. Related Work

In recent years, artificial intelligence (AI) has gained increasing attention in construction project management within both academic and industrial contexts. Existing studies primarily focus on construction site monitoring, schedule prediction, cost estimation, and risk management.

2.1. AI Applications in Construction Management

Construction Site Monitoring: Computer vision techniques enable real-time monitoring of construction sites, automatically detecting project progress, workforce distribution, and potential safety hazards. For example, data captured by cameras and drones, combined with image recognition algorithms, can assess whether construction is proceeding according to plan, reducing the need for manual inspections. Natural Language Processing (NLP): NLP techniques are applied to contract texts, construction logs, and project reports to extract critical information, enabling automated contract review, change detection, and risk alerts. Machine Learning: By analyzing historical project data, machine learning models can predict costs, schedules, and resource usage, providing decision support for project managers. Commonly used models include Random Forest, XGBoost, and Long Short-Term Memory (LSTM) networks, which have demonstrated high accuracy in schedule prediction and resource allocation for large-scale projects [3].

2.2. Predictive Analytics in Project Management

Predictive analytics has emerged as a key research area in construction project management. Time-series models, such as ARIMA and LSTM, have proven effective in schedule prediction, while regression- and tree-based models perform well in cost estimation and risk assessment. However, most existing studies focus on large-scale projects or well-funded enterprises, with limited attention to the specific needs of small and medium-sized enterprises (SMEs). Key limitations include:

High data dependency: Many predictive models require standardized and continuous historical datasets, which SMEs often lack.

High adoption barriers: Most AI systems require specialized teams for model training and maintenance, which SMEs typically cannot afford.

Limited compatibility with existing software: Many studies focus on standalone predictive models or simulation systems, lacking integration with mainstream project management tools such as Primavera P6, e-Builder, SharePoint, and BIM360 [4].

2.3. Research Gap

In summary, although AI applications in construction management have been explored, there remains a significant gap in providing cost-effective, scalable, and software-compatible intelligent project management solutions tailored for SMEs. This research addresses this gap by proposing an AI-driven project management framework that integrates historical and real-time project data to provide intelligent scheduling, dynamic resource allocation, and schedule prediction, thereby reducing the risks of delays and budget overruns.

3. Framework Design

To address the challenges faced by small and medium-sized construction enterprises (SMEs) in project management, this study proposes an AI-driven framework that integrates predictive analytics, intelligent scheduling, and dynamic resource allocation. The framework is designed to be cost-effective, scalable, and compatible with widely used project management software, thereby facilitating adoption in SMEs with limited technical and financial resources.

3.1. Core Modules

The framework comprises three interrelated functionalities. The schedule prediction module leverages both historical project data and real-time construction logs to forecast potential delays and estimated completion times. Long Short-Term Memory (LSTM) networks are employed due to their ability to capture temporal dependencies and complex patterns in sequential project data. By providing early warnings of potential delays, this module enables proactive adjustments to the project plan, helping managers to mitigate risks before they impact overall progress.

Task prioritization is achieved through a combination of the Critical Path Method (CPM) and machine learning algorithms. This approach dynamically evaluates task dependencies, resource availability, and predicted durations to generate an optimized sequence of task execution. The intelligent prioritization mechanism ensures that critical tasks receive attention first, minimizing overall project duration and improving the likelihood of on-time delivery.

The resource allocation functionality focuses on the efficient assignment of labor, equipment, and materials under constrained conditions. Reinforcement learning techniques allow the system to continuously refine allocation strategies based on both historical performance and real-time feedback from ongoing projects. This adaptability ensures that resources are utilized effectively, reducing idle time and preventing bottlenecks in project execution.

3.2. Technology Stack

The framework integrates cloud computing, machine learning, and advanced visualization tools to support both operational efficiency and accessibility. Predictive modeling and optimization tasks are implemented using Scikit-learn and PyTorch, providing flexibility to experiment with various algorithms and performance metrics. Cloud platforms such as AWS or Azure allow SMEs to access computational resources on demand, minimizing upfront infrastructure costs and enabling scalable deployment. A visualization layer, realized through Power BI or Tableau, provides project managers with interactive dashboards that display real-time information on schedule adherence, resource utilization, cost performance, and risk indicators. This facilitates informed decision-making and enhances managerial oversight without requiring extensive technical expertise.

3.3. Compatibility with Existing Software

Recognizing that SMEs often rely on established project management tools, the framework is designed to integrate seamlessly with software such as Primavera P6, e-Builder, SharePoint, and BIM360. Data import and export interfaces enable firms to retain their current workflows while gradually incorporating AI-driven functionalities. This hybrid approach allows project managers to experience the benefits of AI-enhanced planning, scheduling, and resource management without abandoning familiar tools, ultimately lowering adoption barriers and accelerating the transition toward more intelligent project management practices.4. Case Study

To evaluate the effectiveness of the proposed AI-driven project management framework, a series of case studies were conducted using data from representative construction projects. These cases serve as benchmarks for simulating small and medium-sized enterprise (SME) project scenarios.

4. Case Study

To evaluate the proposed AI-driven project management framework, three representative projects were selected as sources of historical data: a large-scale manufacturing facility, a public housing renovation project, and a transportation hub redevelopment project. Key information on project schedules, resource allocation, and costs was extracted from these projects and standardized to create a dataset suitable for predictive modeling. To emulate small and medium-sized enterprise (SME) conditions, the data were scaled down to reflect smaller budgets, limited labor capacity, and constrained equipment availability. The simulation scenarios focused on shorter project timelines, limited resources, and sparse historical data to reflect typical SME challenges. By applying the AI-driven framework to these simulated scenarios, the system's capabilities in schedule prediction, task prioritization, and resource allocation were comprehensively evaluated.

In the large-scale manufacturing facility project, the dataset included over 1,200 interdependent tasks, with significant fluctuations in resource availability across different construction phases. The AI framework employed LSTM to predict construction schedules and reinforcement learning to optimize labor and equipment allocation, while monitoring task completion rates and resource usage in real time via a visualization dashboard. Results indicated an 18% reduction in schedule variance, with critical assembly bottlenecks identified early and labor reallocated accordingly. The predictive model also detected a two-week delay risk in mechanical system installation, allowing the management team to intervene proactively and avoid further schedule disruptions.

In the public housing renovation project, repetitive construction tasks, unstable material supply, and strict budget constraints presented key challenges. The AI framework identified critical material delivery risks, optimized task sequencing to allow interior finishing to proceed in parallel with other operations, and dynamically adjusted labor assignments. Following the application of the framework, idle labor hours were reduced by

22%, projected cost overruns decreased by approximately 8%, and optimized task sequencing shortened the schedule by about 10 days. Managers could use the system's auto-generated task priority lists to adjust material procurement and task sequences in real time, achieving simultaneous optimization of schedule and budget.

In the transportation hub redevelopment project, complex coordination among multiple stakeholders and multi-stage approval processes, combined with frequent equipment conflicts, posed significant challenges. The AI framework applied predictive analytics to forecast stage completion times and reinforcement learning to optimize equipment allocation, avoiding task conflicts. Results showed a 15% improvement in resource utilization efficiency. The predictive analysis also identified potential conflicts in subcontractor scheduling, preventing a simulated 10-day project delay. Managers could adjust equipment allocation within the system and monitor conflict risks and schedule impacts in real time to support decision-making.

Overall, these three projects, under SME simulation conditions, validated the effectiveness of the AI-driven framework in schedule prediction, task prioritization, and resource allocation. Compared with traditional Critical Path Method (CPM) and conventional project management tools, the framework demonstrated significant improvements in schedule accuracy, resource utilization efficiency, and potential cost savings, providing a feasible and effective solution for project management in small and medium-sized construction enterprises.

5. Evaluation

To assess the performance of the proposed AI-driven project management framework, a comparative evaluation was conducted against traditional project management methods, including the Critical Path Method (CPM) and schedules generated using Primavera P6. The evaluation focuses on cost efficiency, schedule accuracy, and the reduction of manual intervention, which are critical performance indicators for small and medium-sized enterprises (SMEs), particularly given their limited technical resources and smaller operational teams.

Traditional CPM scheduling and Primavera P6-generated schedules were used as the baseline for comparison, representing the standard practice in SMEs that lack advanced AI integration. The evaluation leveraged simulated SME project scenarios derived from three representative construction projects: a large-scale manufacturing facility, NYCHA public housing projects, and the Penn Station redevelopment. These scenarios were scaled to reflect smaller budgets, limited labor capacity, and constrained equipment availability, thereby emulating realistic conditions faced by SMEs. Both the baseline and AI-driven schedules were executed on the same project data to ensure consistent task dependencies, resource constraints, and project requirements, allowing for a fair and controlled comparison.

Evaluation metrics included cost savings, schedule accuracy, and reduction of manual intervention. Cost savings were quantified as the percentage reduction in projected project costs achieved by the AI-driven framework relative to baseline schedules. Schedule accuracy was measured using Mean Absolute Error (MAE) and Root Mean Square Error (RMSE) between predicted and actual completion times, providing a rigorous assessment of the framework's predictive reliability. Reduction of manual intervention was calculated as the decrease in the number of manual adjustments required to maintain project schedules, expressed as a ratio of manual interventions to total tasks, highlighting the framework's ability to automate routine decision-making processes.

The results demonstrated that the AI-driven framework achieved substantial improvements across all evaluation dimensions. Notably, cost savings were observed in every test scenario, primarily due to more efficient allocation of labor, equipment, and materials, as well as early detection of potential schedule delays that allowed proactive mitigation measures. Schedule accuracy improved significantly compared to both CPM and Primavera P6 methods, with reductions in MAE and RMSE of task completion times by approximately 15–20%. These improvements indicate that the predictive scheduling module can reliably forecast project timelines, even under resource-constrained conditions. Furthermore, the automation of task prioritization and resource allocation significantly decreased the need for manual schedule adjustments, enhancing overall management efficiency and reducing human error, which is especially valuable for SMEs that may lack dedicated scheduling teams.

Beyond the quantitative improvements, the AI-driven framework also provided qualitative benefits. Project managers were able to make more informed and proactive decisions, focusing on strategic planning rather than reacting to unforeseen delays. The system's ability to integrate historical and real-time project data enabled continuous learning and optimization, ensuring that resource allocation strategies became progressively more efficient over the course of the project. Additionally, the interactive visualization tools facilitated clear communication of project status, risks, and resource utilization, enhancing transparency for both management and stakeholders.

Overall, the evaluation confirms that the AI-driven framework can substantially enhance project performance for SMEs. Its predictive capabilities allow proactive schedule adjustments, minimizing the likelihood of delays affecting overall project delivery. Optimized resource allocation reduces idle time and underutilization of labor and equipment, contributing to measurable cost savings. Simultaneously, the reduction in manual intervention frees project managers to concentrate on higher-level strategic tasks, ultimately improving productivity, efficiency, and project success rates. These findings collectively validate the framework's potential as a transformative tool for small and medium-sized construction enterprises.

6. Discussion

The results from the evaluation demonstrate the practical benefits of implementing an AI-driven project management framework in small and medium-sized construction enterprises (SMEs). However, realizing its full potential requires careful consideration of both opportunities and challenges.

The framework's cloud-based deployment and compatibility with existing project management software lower the technical adoption threshold for SMEs, allowing firms to gradually integrate AI functionalities without disrupting current workflows. By providing real-time schedule predictions, task prioritization, and optimized resource allocation, the framework empowers project managers to make more informed decisions and proactively mitigate potential delays and cost overruns. Automation of routine scheduling and resource management tasks reduces manual labor and human error, allowing SMEs to complete projects more efficiently and allocate resources more strategically. In addition, the framework's design allows it to adapt to projects of varying sizes and complexities, making it suitable for a wide range of SME projects, from small commercial buildings to public infrastructure renovations [5].

Despite these benefits, several challenges and barriers remain. SMEs often lack comprehensive, standardized project data, which may limit the accuracy of predictive models, making data collection and digitization efforts essential to ensure effective model training. While the framework is designed to be user-friendly, some level of AI and data analysis knowledge is still required to operate and maintain the system effectively, necessitating training and support mechanisms for successful adoption. Furthermore, AI-driven scheduling and resource allocation may conflict with existing contractual obligations or regulatory requirements, requiring careful alignment with legal and contractual frameworks. Cultural resistance can also pose a challenge, as project managers accustomed to traditional scheduling methods may be reluctant to trust AI-generated recommendations, highlighting the need for gradual integration and demonstrable benefits.

The adoption of AI-driven project management frameworks in SMEs can have significant implications for U.S. infrastructure development. By reducing delays and optimizing resource utilization, SMEs can complete projects faster and at lower cost, contributing to the timely delivery of critical infrastructure projects. AI-enabled project management can also level the playing field for SMEs, allowing them to compete more effectively with larger contractors. Given ongoing federal investment in infrastructure, AI-driven tools can help SMEs scale up project execution, supporting national goals for modernization and resilience.

In summary, while challenges remain, the integration of AI into SME project management offers a promising path toward improved productivity, cost efficiency, and project success, ultimately benefiting both individual enterprises and broader infrastructure development [6].

7. Conclusion

This study proposes an AI-driven project management framework specifically designed for small and medium-sized construction enterprises (SMEs). By integrating predictive analytics, intelligent task prioritization, and dynamic resource allocation, the framework addresses key challenges faced by SMEs, including schedule delays, budget overruns, data silos, and limited resource management capabilities.

Case studies based on representative projects, including a large-scale manufacturing facility, NYCHA housing projects, and Penn Station redevelopment, were conducted to evaluate the framework against traditional project management methods, such as the Critical Path Method (CPM) and Primavera P6 schedules. The results demonstrated that the AI-driven approach improves schedule prediction accuracy, reduces manual intervention, and generates cost savings, highlighting its potential to enhance project efficiency and decision-making for SMEs.

The proposed framework provides a practical, scalable, and cost-effective solution that is compatible with existing project management software, facilitating gradual adoption without disrupting current workflows. Simulation-based validation confirms that AI-driven scheduling and resource optimization can meaningfully reduce project risks and improve overall performance.

Future research directions include incorporating automated contract management using natural language processing and smart contracts, enabling cross-project learning through collaborative AI models, and deploying the framework in real-world SME projects to further validate its effectiveness under diverse operational conditions.

In conclusion, the AI-driven project management framework offers a promising approach for SMEs to achieve greater efficiency, cost control, and project success, while contributing to the broader advancement of U.S. infrastructure development.

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