

AI-Driven Delay Prediction and Mitigation in Construction Projects

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Abstract

Construction project delays remain a significant global challenge, resulting in cost overruns, contractual disputes, and operational inefficiencies. Traditional scheduling techniques such as Critical Path Method (CPM), Program Evaluation and Review Technique (PERT), and Earned Value Management (EVM) often struggle to address uncertainties and complex interdependencies among project variables. This study proposes an Artificial Intelligence (AI)-driven framework for predicting and mitigating schedule delays using historical construction project data. Machine Learning algorithms, including Random Forest (RF) and Artificial Neural Networks (ANN), are applied to identify major delay factors such as resource allocation, weather conditions, project size, and contractor performance. A dataset of 120 completed construction projects was analyzed to develop a predictive model integrated with Primavera P6 scheduling software. The developed ANN model achieved a prediction accuracy of **88%**, demonstrating strong capability in forecasting potential delays. The results indicate that AI-based predictive tools can significantly improve proactive decision-making, optimize resource utilization, and enhance project planning efficiency in the construction industry.

Keywords: Construction Management, Artificial Intelligence, Machine Learning, Delay Prediction, Schedule Optimization, Risk Mitigation

1. Introduction

Delays in construction projects have become a persistent issue worldwide, negatively affecting project performance in terms of time, cost, and quality. The construction environment is inherently dynamic and uncertain due to factors such as fluctuations in material supply, variations in labor productivity, climatic disruptions, and coordination among multiple stakeholders. These uncertainties make accurate delay prediction extremely challenging.

Traditional project management techniques primarily rely on deterministic scheduling approaches. While methods such as CPM and PERT are useful for planning, they often fail to capture real-time changes and complex relationships among project parameters.

Recent advancements in **Artificial Intelligence (AI)** and **Machine Learning (ML)** offer new opportunities to analyze large volumes of construction data and identify hidden patterns influencing project performance. AI-based predictive models can evaluate multiple project variables simultaneously and generate reliable forecasts for potential delays. This research aims to develop an **AI-driven delay prediction model** and propose mitigation strategies using data-driven insights to improve project management efficiency.

2. Literature Review

Numerous studies have investigated the causes of delays in construction projects using statistical and analytical methods. However, many traditional models oversimplify the interactions among various delay factors.

Alaghbari et al. (2019) identified contractor performance, financial constraints, and project management inefficiencies as major contributors to construction delays in developing countries. Zou et al. (2020) explored the use of data mining techniques for delay analysis and highlighted the potential of machine learning algorithms in identifying complex relationships between project variables. Arditi and Pattanakitchamroon (2021) proposed probabilistic models for delay prediction but noted limitations in adapting these models to evolving project datasets.

In recent years, Artificial Intelligence techniques such as **Artificial Neural Networks (ANN)**, **Support Vector Machines (SVM)**, and **Random Forest algorithms** have gained significant attention in construction management research. These models demonstrate improved prediction accuracy due to their ability to capture nonlinear relationships and learn from historical project data.

Despite these advancements, many existing studies lack integration with practical project management tools and fail to provide actionable mitigation strategies. Therefore, this study attempts to bridge this gap by developing an AI-based predictive model integrated with **Primavera P6** scheduling software to enable real-time delay monitoring and proactive decision-making.

3. Research Methodology

3.1 Data Collection

The dataset used in this study was collected from **120 completed infrastructure and building construction projects across India between 2018 and 2024**. Each project record contained approximately **25 variables**, including project duration, project cost, contractor type, labor availability, weather conditions, resource allocation, project complexity, and change orders.

3.2 Data Preprocessing

The collected dataset underwent several preprocessing steps to ensure accuracy and reliability. Missing values were handled using data imputation techniques, while normalization methods were applied to



standardize the data. Correlation analysis and **Principal Component Analysis (PCA)** were conducted to identify the most influential variables contributing to project delays.

3.3 Model Development

Two Machine Learning models were developed for delay prediction:

Random Forest (RF):

Used for feature importance analysis and classification of delay factors.

Artificial Neural Network (ANN):

Used for capturing nonlinear relationships and predicting delay probability.

The dataset was divided into **70% training data and 30% testing data**. Model development and training were conducted using **Python-based libraries including Scikit-learn and TensorFlow**.

3.4 Integration with Project Management Tools

To improve practical applicability, a custom interface was developed to integrate the predictive models with **Primavera P6** scheduling software. This integration enables project managers to receive real-time alerts regarding potential delays based on predictive analytics.

3.5 Model Evaluation

The performance of the developed models was evaluated using the following metrics:

- Mean Absolute Error (MAE)
- Root Mean Square Error (RMSE)
- Coefficient of Determination (R^2)
- Confusion Matrix Accuracy

These evaluation indicators helped assess prediction reliability and model efficiency.

4. Results and Discussion

The experimental results demonstrate that the **Random Forest model achieved an accuracy of 85%**, whereas the **Artificial Neural Network model achieved a higher accuracy of 88%**, outperforming traditional regression-based prediction models which typically showed an average accuracy of approximately 72%.

Feature importance analysis revealed several critical factors contributing to project delays:

Delay Factor	Importance Weight
Inadequate resource planning	0.28
Design changes	0.22

Delay Factor	Importance Weight
Weather disruptions	0.18
Contractor experience	0.15

The integration of predictive analytics with **Primavera P6** allowed project managers to visualize potential schedule risks before actual delays occurred. The developed predictive dashboard generated early warning signals, enabling timely corrective actions such as workforce reallocation, schedule adjustments, and improved resource planning.

The results clearly demonstrate that **AI-based delay prediction models can significantly improve project management efficiency by enabling proactive rather than reactive decision-making.**

5. Conclusion

This research highlights the potential of Artificial Intelligence in transforming construction project management practices. The proposed AI-driven framework successfully predicted project delays with high accuracy and provided actionable insights for mitigation.

The integration of machine learning models with traditional project management tools can significantly enhance planning accuracy, reduce project risks, and improve overall project performance.

Future Scope

Future research may focus on:

- Integrating **IoT sensor data** for real-time construction site monitoring
- Expanding predictive models to forecast **cost overruns** and **risk probability**
- Applying AI models for **sustainability and energy efficiency evaluation in construction projects**

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