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Artificial Intelligence in Healthcare Construction Scheduling: Comparative Analysis of MLP, SVR, and Decision Trees

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Abstract

Efficient scheduling of healthcare infrastructure projects plays a crucial role in enhancing public health services by ensuring timely delivery and optimal resource allocation. This study investigates the application of Artificial Intelligence (AI), particularly the Multi-Layer Perceptron (MLP) neural network, in predicting project completion times for healthcare construction projects. A dataset of 300 real-world healthcare projects in Iran was analyzed, incorporating variables such as budget, number of beds, geographic location, and contractor profile. The MLP model demonstrated superior predictive performance compared to Support Vector Regression (SVR) and Decision Tree Regression, achieving a Mean Absolute Error (MAE) of 12.6 days and a Root Mean Square Error (RMSE) of 16.8 days with an R^2 score of 0.94. These results highlight the potential of AI-driven models to support data-informed decision-making in healthcare project management, reduce scheduling uncertainties, and improve project success rates. The findings offer practical implications for policymakers and project managers seeking to modernize infrastructure planning through intelligent forecasting techniques.

Keywords: Healthcare project scheduling, Artificial Intelligence (AI), Multi-Layer Perceptron (MLP), Machine Learning, Project duration prediction.

1. Introduction

In today's world, healthcare projects hold a critical role in enhancing public health and welfare. Effective management of these projects, particularly in terms of scheduling, can significantly impact the quality and efficiency of healthcare services. Accurate scheduling of healthcare projects is essential for optimal resource allocation, cost reduction, and improved treatment outcomes (Kerzner, 2017).

Precise scheduling in healthcare projects is vital for ensuring high productivity and efficiency. This includes the optimal management of human and financial resources, reducing delays, and preventing resource wastage. For instance, in the construction and equipping of hospitals, improper scheduling can delay patient access to essential services, which can negatively affect public health (Meredith & Mantel, 2014). Despite its importance, managing healthcare project schedules is fraught with challenges. One of the main issues is the high complexity of these projects due to the diversity of activities and interactions between various units. Additionally, accurate scheduling is difficult due to unpredictable factors such as changes in healthcare needs and the occurrence of health crises (Gardiner, 2005). These issues can lead to patient dissatisfaction, increased costs, and reduced quality of services. In response to these challenges, advanced technologies like artificial intelligence (AI) offer promising solutions. AI, with its capability to analyze large datasets and make precise predictions, can play a significant role in enhancing the scheduling of healthcare projects. Machine learning algorithms can analyze historical and current data to identify complex patterns and provide more accurate scheduling. Additionally, AI can improve decision-making and reduce human errors, contributing to better overall management of healthcare projects (Pinto, 2019).

Therefore, leveraging AI not only helps address scheduling challenges in healthcare projects but also enhances the overall quality and efficiency of healthcare services. This paper will explore AI methods and techniques in analyzing healthcare project schedules and present a proposed model for improving these schedules (lock. 2020).

2. Literature Review

Numerous studies have highlighted the critical importance of efficient scheduling in healthcare projects. These studies often focus on the challenges and potential solutions to improve scheduling accuracy and efficiency.

A study by Kerzner (2017) emphasizes the role of effective project management techniques in ensuring timely completion of healthcare projects, highlighting the need for accurate scheduling to avoid delays and cost overruns. Similarly, Meredith and Mantel (2014) discuss the complexities involved in healthcare project management, particularly the need for precise coordination among various stakeholders and activities.

Research by Pinto (2019) identifies common pitfalls in healthcare project scheduling, such as resource misallocation and unforeseen delays. Pinto suggests the adoption of advanced project management tools to mitigate these issues. Lock (2020) further elaborates on the necessity of robust scheduling frameworks to manage the dynamic nature of healthcare projects effectively.

Zwikael and Smyrk (2019) explore the impact of project scheduling on organizational value creation in the healthcare sector, emphasizing that better scheduling leads to improved patient outcomes and higher efficiency. Gardiner (2005) introduces strategic planning approaches that can enhance the scheduling processes in complex healthcare projects.

Turner (2014) discusses the application of project-based management techniques in healthcare projects, stressing the need for integrating modern technological solutions to handle scheduling complexities. The studies collectively underline that traditional scheduling methods often fall short in addressing the dynamic and multifaceted nature of healthcare projects.

Numerous studies have highlighted the critical importance of efficient scheduling and management in healthcare projects. These studies often focus on challenges and potential solutions to improve scheduling accuracy and operational efficiency.

A study by Kerzner (2017) emphasizes the role of effective project management techniques in ensuring the timely completion of healthcare projects. Meredith and Mantel (2014) elaborate on the complexity of such projects, requiring precise coordination among various stakeholders. Pinto (2019) and Lock (2020) underline the need for robust scheduling frameworks to minimize risk and optimize resource utilization.

Zwikael and Smyrk (2019) discuss the strategic value creation enabled by better scheduling, while Gardiner (2005) offers structured planning methods for high-risk healthcare projects. Turner (2014) also advocates the adoption of project-based management models, particularly in environments characterized by dynamic requirements.

In the Iranian context, several contributions by Zandi Doulabi and colleagues provide critical insight into success factors for healthcare infrastructure. Their 2016 study in Procedia Engineering identified key CSFs such as stakeholder coordination, financial planning, and technical capability (Zandi Doulabi & Asnaashari, 2016). This was further developed through a qualitative framework presented at CITC-9, emphasizing thematic patterns extracted from expert interviews (Zandi Doulabi & Asnaashari, 2017). More recently, a quantitative study using Analytic Hierarchy Process (AHP) was employed to prioritize CSFs in healthcare projects, offering structured decision-making insights (Zandi Doulabi et al., 2024a). Additionally, their 2024b study addressed sustainability and energy efficiency in green hospitals, highlighting the interplay between project performance and environmental responsibility (Zandi Doulabi, et al.,2024b).

These national studies provide a rich foundation for integrating AI-based predictive models into the scheduling and management of healthcare construction projects, especially within the context of regional constraints, evolving policies, and sustainability objectives.

3. Introduction to Basic Concepts of Artificial Intelligence and Machine Learning

Artificial Intelligence (AI) and Machine Learning (ML) have emerged as powerful tools in various domains, including healthcare project management. AI involves the simulation of human intelligence in machines, enabling them to perform tasks that typically require human intelligence, such as learning, reasoning, and problem-solving (Russell & Norvig, 2020).

Machine Learning, a subset of AI, involves the development of algorithms that allow computers to learn from and make predictions based on data. Goodfellow, Bengio, and Courville (2016) define ML as a method of data analysis that automates analytical model building, enabling systems to learn from data, identify patterns, and make decisions with minimal human intervention.

Deep Learning, a more advanced subset of ML, uses neural networks with many layers (LeCun, Bengio, & Hinton, 2015). This approach has been particularly successful in complex pattern recognition tasks, making it highly applicable in predicting project schedules where multiple variables and data points must be considered.

The application of AI and ML in scheduling involves using algorithms to analyze large datasets, identifying patterns and predicting future events. For example, historical project data can be used to train ML models to predict potential delays and suggest optimal scheduling adjustments.

AI's ability to process vast amounts of data quickly and accurately makes it an invaluable tool in healthcare project management. By leveraging AI and ML, project managers can enhance scheduling accuracy, optimize resource allocation, and improve overall project efficiency, leading to better patient outcomes and cost savings

4. Methodology

4.1 Methods and Techniques of Artificial Intelligence in Scheduling

Artificial Intelligence (AI) offers various techniques that can enhance the prediction of project schedules, particularly in the complex domain of healthcare construction. Three primary approaches are explored in this study:

- Neural Networks: Modeled after the human brain, neural networks consist of layers of interconnected nodes that can learn complex patterns from data. They are particularly effective for regression tasks involving nonlinear relationships (Goodfellow, Bengio, & Courville, 2016).

- Decision Trees: These supervised learning models divide data into subsets based on decision rules, forming a tree-like structure. They are easy to interpret and useful for identifying the most influential factors in scheduling (Quinlan, 1993).

- Deep Learning: A subset of machine learning that uses multi-layered neural networks to process large-scale and complex data. Deep learning is highly effective in tasks requiring abstraction and pattern recognition, such as predicting project timelines from multifactor datasets (LeCun, Bengio, & Hinton, 2015).

4.2 Application of AI Algorithms in Scheduling Prediction

- Neural Networks have been used successfully to predict the duration of construction projects by identifying nonlinear dependencies between project features. For example, Zhang et al. (2019) used neural networks to predict delays in infrastructure projects with high accuracy.

- Decision Trees, due to their clarity and interpretability, are widely adopted in decision support systems. Petropoulos et al. (2018) demonstrated their use in software project time prediction, emphasizing their effectiveness in early-stage planning.

- Deep Learning models have been applied by Cheng et al. (2020) to large infrastructure scheduling problems, showing significant improvements over traditional scheduling methods.

4.3 Case Studies and Practical Applications

- In healthcare project management, neural networks have been used to predict durations of different project phases by analyzing diverse factors such as weather, labor efficiency, and equipment availability (Rajkomar et al., 2018).
- In manufacturing, decision trees have helped optimize production schedules, reducing idle time and increasing resource efficiency (Kusiak, 2018).
- In software engineering, deep learning has been used to estimate delivery timelines based on past performance metrics and code complexity (Jorgensen, 2019).

4.4 Multi-Layer Perceptron (MLP) for Predicting Healthcare Project Completion Time

Introduction

The MLP is a powerful feedforward artificial neural network consisting of three or more layers. It is especially effective in modeling complex, nonlinear relationships that are typical in project scheduling data (Goodfellow et al., 2016).

Architecture

- Input Layer: Includes project features such as region, project size, number of beds, contractor experience, and budget.
- Hidden Layers: In this study, the network consists of five hidden layers with decreasing neuron counts (64 → 32 → 16 → 8 → 4), using ReLU activation functions.
- Output Layer: Provides the final prediction of project completion time (in days) using a linear activation function.

Training Process

The dataset of 300 real-world healthcare projects was divided into training (70%) and testing (30%) subsets. Training was conducted using the Adam optimizer and mean squared error as the loss function. Overfitting was prevented through dropout layers and early stopping strategies.

Implementation

The model was built in Python using TensorFlow and Scikit-learn libraries. Data preprocessing was performed with Pandas and NumPy.

5. Results and Discussion

5.1 Model Performance Evaluation

The MLP model showed exceptional accuracy in predicting project durations, as evidenced by the following metrics:

Mean Absolute Error (MAE): 12.6 days

Root Mean Square Error (RMSE): 16.8 days

R^2 Score: 0.94

These results indicate that the model accurately captures the complexity of healthcare project scheduling and produces highly reliable forecasts.

5.2 Comparative Analysis with Other Models

Model	MAE (days)	RMSE (days)	R^2 Score
MLP	12.6	16.8	0.94
SVR	19.2	24.7	0.88

Decision Tree	27.4	35.1	0.79

Table1: Comparative Analysis with Other Models

The MLP model significantly outperforms both SVR and Decision Tree models. Its superior accuracy is attributed to its capacity to learn intricate relationships from diverse and nonlinear data sources, which is essential in healthcare projects influenced by multiple unpredictable variables.

5.3 Error Analysis

Residual analysis showed that the prediction errors are symmetrically distributed around zero with no observable patterns, suggesting that the model does not exhibit systemic bias. Only 4% of the predictions showed absolute errors above 45 days, mostly due to unexpected policy changes or extreme regional delays not captured in the training dataset.

5.4 Interpretation and Implications

The model’s high predictive accuracy enables:

Proactive scheduling based on realistic timelines,

Efficient resource allocation, and

Strategic decision-making in healthcare infrastructure planning.

By leveraging this AI-based approach, healthcare managers can anticipate challenges early and improve both financial and operational outcomes.

6. Discussion

This study demonstrated the potential of Artificial Intelligence—specifically, the Multi-Layer Perceptron (MLP) neural network—in accurately predicting the completion time of healthcare construction projects. By analyzing a comprehensive dataset of 300 real-world hospital infrastructure projects in Iran, the MLP model outperformed traditional machine learning algorithms such as Support Vector Regression (SVR) and Decision Tree Regression in all major performance metrics, including MAE, RMSE, and R^2. The model's ability to capture nonlinear relationships and process complex, multi-dimensional inputs enabled a significant reduction in prediction error and improved scheduling precision.

The integration of AI into healthcare project scheduling offers a promising avenue for addressing longstanding challenges in project delivery, such as cost overruns, resource inefficiencies, and service delays. Accurate time prediction empowers project managers to proactively identify bottlenecks, allocate resources more efficiently, and implement preventive measures well before delays occur. This is particularly critical in the healthcare sector, where delays in infrastructure development can directly impact patient access to essential services and overall public health outcomes.

Moreover, the findings of this research have strong implications for evidence-based policymaking and strategic infrastructure planning. The ability to predict project timelines with high accuracy supports more transparent budgeting, enhanced contractor oversight, and realistic deadline setting. In countries facing financial constraints and infrastructure gaps, AI-enabled planning tools such as the MLP model can significantly enhance return on investment and project success rates.

Future research can expand upon this study in several directions. First, integrating hybrid AI approaches—such as combining MLP with fuzzy logic, genetic algorithms, or reinforcement learning—may further improve performance in uncertain or rapidly changing environments. Second, incorporating real-time data streams (e.g., labour availability, weather, and supply chain disruptions) can make the models dynamic and adaptive. Third, validating the model across other countries, healthcare systems, and project types will be crucial for testing its generalizability and robustness.

In summary, this study provides strong empirical evidence for the utility of deep learning in healthcare infrastructure management. As healthcare systems around the world strive for greater resilience, efficiency, and responsiveness, AI-powered scheduling models can become an essential component of modern project management toolkits.

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