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Predicting the Duration of Construction Projects Using Combined Fuzzy Artificial Neural Networks and Metaheuristic Algorithms

Abstract

A delay is an action or occurrence that extends the time allotted in the contract to complete a certain task, either as an expansion of the activity's duration or a postponement of its start date. If the projects are not completed on time, some will lose their technical and economic basis, squandering public resources. This study has attempted to propose a project time prediction model utilizing a mix of fuzzy neural networks and genetic algorithms, considering many factors of engineering, labor, management, materials, employer, contractor, weather conditions, and time performance index. The MSE accuracy technique yielded a value of 0.37, while the RMSE accuracy method yielded a value of 0.61, indicating that the neural network is quite acceptable and useful for prediction.

Keywords: *Project Execution Time, Forecast, Fuzzy Neural Network, Genetic Algorithm*

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1. Introduction

A country's economic growth hallmarks are its development plans, which are significant criteria and indications of its economic success (Oke et al., 2016). As a result, a nation's progress, prosperity, and excellence are dependent on the success of its development projects, and the success of development project implementation necessitates mechanisms and factors until the cycle of events is optimally and timely predicted and completed at the lowest cost and highest profit (Ogano & Pretorius, 2012). Today, most of a country's capital is committed to development and infrastructure projects, particularly in emerging nations. The success of a society's development initiatives is one of the variables that determine its economic growth and development.

The fundamental challenge that most large projects confront is delays in various phases and the project's completion (Yang & Wei, 2010). A delay is an action or occurrence that extends the time allotted in the contract to complete a certain task, either as an expansion of the activity's duration or a postponement of its start date. If the projects are not completed on time, some will lose their technical and economic basis, squandering public resources. As a result, one of the primary concerns of project managers is the ability to execute the project on time and within budget.

According to Iranian specialists and project managers, the time dimension of projects is currently more significant than the cost dimension. As a result, the adoption of performance indicators that show the project's overall health in terms of time and project time projection indicators that estimate the project's final time based on the current trend has skyrocketed. The duration of building projects is explored in this study by first identifying the effective elements in project delays and then presenting its model using a mix of fuzzy artificial neural networks and meta-heuristic algorithms.

2. Literature Review

Projects are a collection of distinct actions designed to accomplish a certain aim (Herroelen et al., 1997). Project activities are planned for future implementation before execution, and the original project timeline is established (Bhoyar & Parbat, 2014).

In 2018, Barros et al. used artificial neural networks to predict the cost of constructing Brazilian motorways. The backpropagation technique was used to train several network designs with 10, 15, and 20 neurons. Data from fourteen roadway projects in Brazil were collected and analyzed. After much trial and error, eleven characteristics that impacted the final building costs were discovered. The mean cost estimate for the best-case scenario was 99 percent. This pilot research proved that the tool could be utilized in projects in Brazil and that government agencies might use it in the future. Hosseini et al. investigated the balance between the three criteria of time, cost, and quality in an open road building project in a 2017 study. They want to solve their three-objective model using a genetic algorithm and a responsive batch to cut project costs and time while improving quality. For this, they rely on two sources of personnel and supplies. Different time, cost, and quality might result from combining the two sources and the time constraints. Aziz & Abdel-Hakam et al. published "Investigating the Causes of Delays in Road Construction Projects in Egypt" in 2016. Development delays are typical in Egypt's civil engineering projects, particularly road construction. The most common causes and groupings of delays in the research are reviewed, and future ideas are offered to regulate and eliminate delays in road building projects based on the study of case studies.

Mensah et al. developed a technique for calculating the length of a bridge construction project in 2016. The neural network was employed in this study, and two independent variables were used as input and real-time as output variables to create the model. The findings revealed that the suggested model is a

good fit for calculating bridge project duration. Vahdani et al. used a fuzzy neural model to predict the desired time for building projects in a 2016 research. The output of the suggested predictive model based on a local linear fuzzy-neural model (LLNF) trained using a local linear model tree learning method is beneficial for evaluating the state of a project at different time horizons (LOLIMOT). Risk Management in Construction Projects, research by Iqbal et al. in 2015, is based on a questionnaire-based survey on risk management in Pakistan construction projects. According to the findings, appropriate program dissemination and correlation are critical during the implementation phase. Shehu et al. presented a linear model for forecasting project length based on contract time in their 2015 paper, Analysis of Characteristics Affecting the Completion Time of Malaysian Construction Projects. The findings suggest that critical information aids in the reduction of project delays in Malaysian building projects. According to Monghasemi et al. (2015), any construction project's planning phase contains many, often contradictory criteria that must be maximized simultaneously. The suggested technique effectively boosted the building project's planning efficiency by analyzing each planning option's performance based on numerous criteria (e.g., time, cost, and quality). Masrom et al. investigated the success measures for significant infrastructure projects in Malaysia in 2015.

The findings demonstrate that crucial features may be used to aggregate success measures for infrastructure project implementation, which appears to be significant for prioritizing project difficulties more systematically. Hazim et al. published a research paper titled "Delays and Costs in Jordanian Road Construction Projects" in 2015. According to this study, 19 reasons might cause delays in road building projects. Land and weather conditions are the key variables determining time and cost in road construction projects in Jordan, according to the findings of this study. Hasan and colleagues published "Investigating Delays in Road Projects in Bahrain" in 2014. The findings show that various factors contribute to contractor delays, including inadequate planning and timing. The delay in making decisions is one of the key causes for the owner, the MOW. The lack of experience is one of the most serious issues with therapy. Furthermore, cost and time increases were two of the most common consequences of delays.

Munyoki (2014) investigated the elements that influence building projects. The study above examined how contract duration influences construction projects and how project funding, supervision, and inspection affect project completion. In a research published in 2013, Hamid looked at creating a conceptual framework on crucial success criteria. For a long time, several scholars have attempted to discover the aspects that contributed to the project's success.

3. Method

Accurate planning and scheduling are critical components in ensuring that a construction project is completed on time and within budget (Chan, 1996). A good and adequate time planning and control system is required for a construction project since it allows for successful administration of a single project while also requiring the management of several projects simultaneously (Griffth et al., 2014). Projects are carried out in the real world, and uncertainty is one of the primary features of these contexts. The activities, time, and expenses associated with completing projects are all sources of uncertainty. Uncertainty is a system attribute that represents a lack of human understanding of a system and its current stage of development (Ivanov & Sokolov, 2009). The following are some of the retrieved instances from the literature review on the elements that cause project delays:

- Employer's managerial weakness
- Delay in payment of wages to the contractor
- Lack of skilled manpower
- Lack of executive vision and designers' workshop
- Mistakes of manpower during work
- Lack of strong financial strength of the contractor
- Approval of workshop plans
- Lack of liquidity at the time of construction
- Design errors and changes
- Conflicts in the work schedule of subcontractors
- Make decisions
- Incomplete workforce skills

To collect data in collaboration with Ryan Sazeh Consulting Engineers Company and to consider various aspects of engineering, labor, management, materials, employer, contractor, weather conditions, and time performance index in terms of quality performance in 24 different weeks during the first half of 1998 were implemented, and the results were reported.

Improved fuzzy neural networks with meta-heuristic methods are employed in this study to estimate project time and studies. Artificial neural networks are a type of computational technology that attempts to offer a mapping between the input space (input layer) and the desired space (output layer) by learning to recognize the underlying links between the data. The information received from the input layer is processed and provided to the output layer by the hidden layer or layers. According to the structure of an artificial neural network, its main features are high processing speed, pattern learning ability, ability to generalize knowledge after learning, flexibility against unwanted errors, and not causing significant disruption in case of problems in some of the connections due to the distribution of network weights; a trained neural network

can be used to predict outputs appropriate to a new data set. To research phenomena involving nonlinear equations, adaptive fuzzy inference systems based on artificial neural networks are commonly utilized. As a result, combining fuzzy systems based on logical principles and artificial neural network approaches that can extract knowledge from numerical data allows for using human knowledge in addition to human knowledge in the model creation. Finally, metaheuristic methods are used to optimize this fuzzy neural network. The genetic algorithm is employed in this research. Generally, the optimization strategy is utilized to look for perplexing response spaces and feature many local extremes. The genetic algorithm begins its search with a random sample population and then optimizes using random functions depending on the objective function's values. The MATLAB software environment combines a fuzzy neural network and a genetic algorithm.

4. Implementing a Combined Fuzzy Neural Network Model and the Genetic Algorithm

The input data such as engineering, labor, management, materials, employer, contractor, and weather conditions of the output data linked to the time performance index were determined in MATLAB software after calling the data. The data was separated into two categories: training and testing, which accounted for 70% and 30% of the total. Sugeno fuzzy neural network was created, and a genetic algorithm was used to optimize it. The evolutionary algorithm's objective function is the root mean square error (RMSE) approach, and the population formed in 100 repetitions is 25. Various measures such as mean square error (MSE) and root mean square error (RMSE) are used to assess the forecast's suitability. Equations (1)-(2) can be used to express these characteristics.

(1)

$$MSE = \frac{\sum_{i=1}^{n} e_i^2}{n}$$

(2)

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} e_i^2}{n}}$$

The number of predictions in this equation is n, and the prediction error is e_i, calculated as the difference between the expected and actual values. The findings indicate the fuzzy neural network and the evolutionary algorithm function together in Figures 1 and 2. The error of 17 training data and 7 test data was investigated in Figures 1 and 2. The MSE accuracy technique of 0.09 and the RMSE accuracy method of 0.29 were used to compute the training data. The findings reveal that the prediction model is quite accurate.

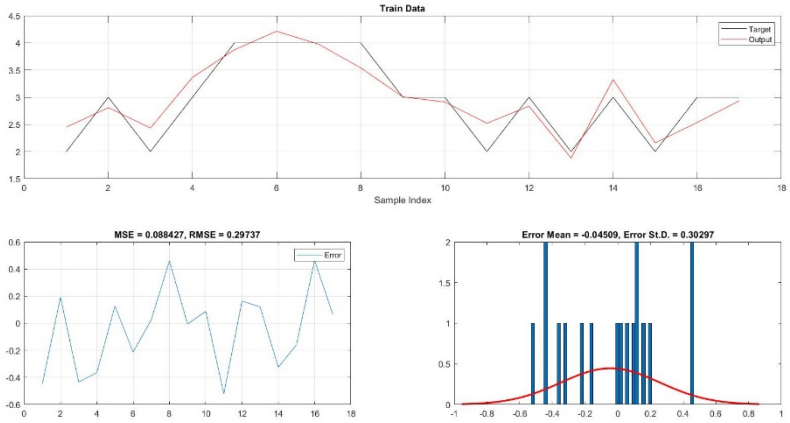

Figure 1. Predictive training values obtained from a combined fuzzy neural network with a genetic algorithm

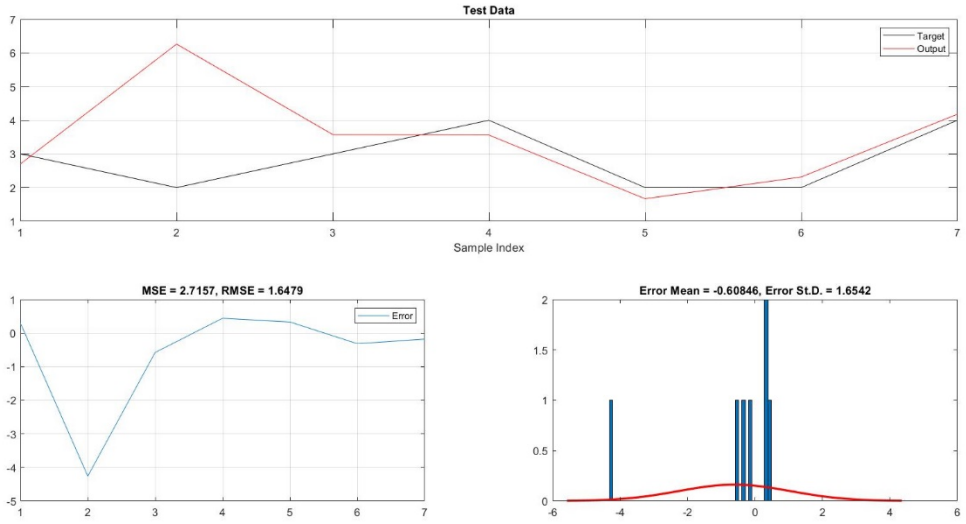

Figure 2. Predictive test values obtained from the combined fuzzy neural network with the genetic algorithm

5. Conclusion

Numerous studies have determined that using fuzzy neural networks in conjunction with meta-heuristic algorithms to estimate project execution time has not been explored. The database was built in 24 weeks to analyze the input data relevant to the time performance index, such as engineering, labor, management, materials, employer, contractor, and weather conditions. The mean error squared (MSE) and root means square error (RMSE) were calculated by two methods of approximating the model's accuracy by presenting a combined model of genetic algorithm and fuzzy neural network. It was determined that the model is 0.37 with the MSE accuracy method and 0.61 with the RMSE accuracy method, and this neural network is very suitable and usable for prediction. The findings suggest that the proposed approach may produce more accurate and consistent predicting outcomes. One of the flaws of value-added management is that it only uses past data from the project whose outcomes are projected to estimate the cost and schedule of project completion. Given the multiple issues in creating other similar projects, this modest amount of data does not appear to be sufficient to forecast project outcomes. Considering the effectiveness of neural networks, it can be argued that their capacity to tackle complicated and poorly organized issues and utilize data from many projects can assist managers in making better judgments. Contractors and employers were highlighted as important variables that may have improved prediction outcomes.

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