A Review on the Application of Artificial Neural Networks for Forecasting Construction Costs

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Abstract – *Accurate cost estimation is a crucial part of construction project planning and management. In recent years, the application of Artificial Neural Networks (ANN) are emerging as a powerful tool for predicting project costs. ANNs offer data-driven framework for cost prediction, facilitating the utilization of extensive historical project data. On training ANNs with historical data, ANNs can learn intricate association among project attributes and costs, enabling better accuracy. The study presents the application of ANN for forecasting the construction costs with prime focus on exploring their predictive performance on various datasets. The review addresses systematic procedure for integrating construction project data with the computing system, principles of neural networks, feature selection for modelling, data pre-processing techniques, existing ANN training algorithm and model performance validation.*

***Key Words*:** Artificial Neural Network (ANN), data-driven, cost prediction, computing system, feature selection, data pre-processing, training algorithm, performance validation.

1. INTRODUCTION

Cost estimates are vital part of construction projects, as costs form a fundamental criteria for performing feasibility studies in project management. As the project progress through each stage of execution, the estimated cost may differ from the actual cost. This is due to uncertainties during execution. Due to discrepancies arising from lack of data and knowledge at conceptual stage cost estimating is highly challenging. Therefore it is essential to pay maximum attention in producing reliable estimates at early stages of construction projects. Establishing accurate costs in the course of pre-construction stages is necessary for maintaining a disciplined approach in the construction process. Cost estimation involves dealing with numerous variables prompting efforts to address and incorporate these factors to achieve more precise estimates. Due to the unique nature of construction projects, and the prospect of encountering difficulties during execution, projected costs are always likely to face escalations. To limit the effects of such conditions, it is highly important to include the factors that are prone to arise for reliable estimates. The experience form previous projects can help constructors minimize mismanagements and escalate the overall success of comparable future projects. Hence techniques that help develop preliminary estimates that relate non-linear relationships with controlling factors would be of a substantial benefit. ANNs are specifically designed for predictions. The models rely on extensive set of building information from past projects. By leveraging this building information, the models are trained to predict outcomes.

1.1 ARTIFICIAL NEURAL NETWORKS

The Artificial Neural Network is a machine learning approach developed with a high caliber of human brain. The network acquires knowledge by learning. Motivated by the functionality of the human brain, artificial neural networks make computers work more like a human brain. The networks use various layers of mathematical processing system to sense the information that is fed as input. Predictive neural networks are capable to detecting complex relationships between variables. In the training phase, these models initially learn the structure of the data, analyze the trends of historic data and decide the way to predict the familiar output value using the predictor variable. ANN has the ability to recollect and respond appropriately to previous experiences. In testing phase, new data is tested to realize the predictive efficacy of the model. Training ANN is computationally intensive, while a fully trained neural network applied to the test data has modest computational requirements. The network adjusts its weights and biases to minimize the difference between the predicted outputs and actual outputs. This ability to detect intricate patterns enable ANNs to be highly effective in construction cost predictions. However it is important to train and validate the model to ensure reliable and accurate predictions.

2. REVIEW OF LITERATURE

Extensive research performed by scholars in the preceding years has delivered a range of literatures focused on the application of Artificial Neural Networks for forecasting the cost of construction projects. These studies have aimed to investigate and identify the factors that improve the precision of cost estimation using ANN based models. By scrutinizing various elements of cost forecasting, researchers have made significant contributions to understand the complexities of utilizing ANNs for predicting construction costs, including factors such as project characteristics, input parameters, training algorithm and model performance evaluation.

2.1 INTERNATIONAL STATUS

Alqahtani et al (2013), focused on the development of a user-friendly and structured framework for Life Cycle Cost Analysis (LCCA) in construction projects, aimed at simplifying complex processing. The framework introduced in this work acknowledges the role of Artificial Neural Networks (ANNs) in computing the overall costs associated with construction. The author compares back propagation method using MATLAB software and spread sheet optimization using Microsoft Excel solver. The optimal network configuration for the models was found to consist of 19 hidden nodes, with the tangent sigmoid transfer function employed for both methods. Both the spreadsheet neural network model and back-propagation technique exhibit strong capabilities in estimating the total running cost of the system, achieving average accuracies of 99% and 98% respectively. These results emphasize the high level of accuracy and reliability demonstrated by both approaches in accurately predicting the overall running cost.

Jafarzadeh et al (2014), discussed the application of ANN in predicting the cost required for seismic retrofit construction. Data has been collected from one hundred and fifty-eight earthquake-prone public buildings for model development. The utilization of ANN indicate that the generalization and learning potential of the model is highly influenced by the number of hidden neurons. The study also noted that overlearning becomes more severe as the number of independent variables increases, emphasizing the need to control it, particularly with a higher number of input variables. Additionally, increasing the number of hidden layers in the ANN model showed potential for improving its performance. Overall, this research provides valuable insights into optimizing generalization ability and addressing challenges related to hidden neurons, learning parameters, and input variables in ANN models.

El-Sawalhi et al (2014) aimed to develop an Artificial Neural Network (ANN) model for early cost estimation of building projects in the Gaza Strip. The ANN was used to predict the future parametric cost of the project. Among the different models tested, the Multilayer Perceptron network model (MLP) demonstrated the highest accuracy, providing more accurate results. The MLP model consisted of an input layer with 11 neurons representing 11 parameters, a hidden layer with 22 neurons, and an output neuron representing the predicted cost. The model utilized the Tanh transfer function and the Momentum learning rate from the Back-propagation algorithm. The adopted model achieved an accuracy performance of 94%, indicating a strong performance with minimal difference between the estimated output and the actual budget value. This model proves to be highly capable of providing reliable cost estimates at the early stages of a project.

Michael Juszczyk (2017), discussed the use of Artificial Neural Networks (ANNs) for nonparametric cost estimation in construction, with a specific emphasis on conceptual or early stage project estimates. ANNs have shown successful application across various building types and projects. It is evident that the key features of ANNs, such as their ability to model cost without assuming functional relationships and their capacity for knowledge generalization, make them well-suited for detailed cost estimation.

Gante et al (2022), utilized Artificial Neural Network (ANN) to develop a forecasting model for accurately predicting future costs of road improvements. A comparison was made between the performance of the neural network prediction model and a Multiple Linear Regression (MLR) model. The results showed that the neural network model outperformed the MLR model in terms of prediction accuracy. The Mean Absolute Percentage Error (MAPE) for the final neural network model was recorded as 0.541%, while the MLR model achieved a MAPE of 2.480%. These findings highlight the superiority of the neural network model in accurately forecasting costs compared to the traditional MLR approach.

2.2 NATIONAL STATUS

Mahalakshmi et al (2018) developed an ANN model to estimate the cost of Highway projects. A dataset from 52 road projects completed from 2014 to 2017 was used for analysis. Design specification such as type of pavement, alignment, design speed, and slope; Locality factors includes the number of bridges, number of stream crossings, and volume of earthwork; other factors such as duration, acquisition cost, and inflation are all considered. The dataset has been separated as 70% for the training set, 15% for the test set, and the remaining 15% for validation. Statistical parameters say mean squared error, mean absolute error, mean absolute percentage error, and accuracy performance are analyzed and the values obtained are significantly low indicating high accuracy. The multilayer feed-forward with backpropagation has been used as the algorithm for the model. The developed model produced a correlation coefficient (R) value of 0.94664. The ANN model structures with ten input factors, six hidden layers, and an output layer have an accuracy of 95.2%.

Chandanshive et al (2019) estimated the construction cost using Artificial Neural Networks. To develop an Artificial Neural Network (ANN) model, two different approaches were introduced: early stopping and regularization. These approaches aimed to enhance the generalization capability of the neural networks and prevent overfitting. The study found that the regularization approach outperformed the early stopping approach. The regularization approach, specifically the 11-3-1 network architecture with the trainbr training function, demonstrated superior performance in terms of regression metrics and error measurements.

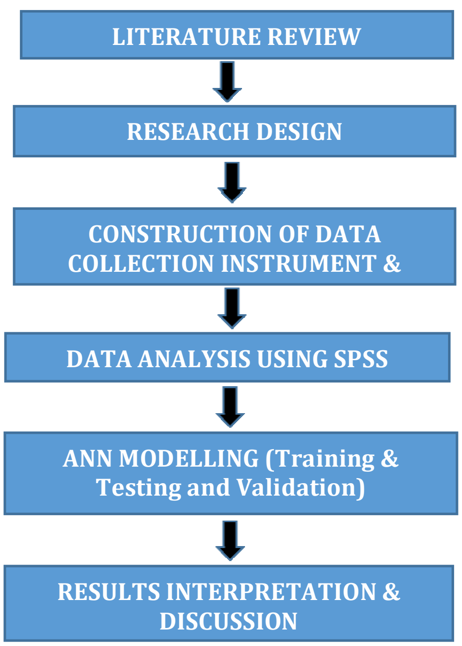
Priti Ashok Patil et al (2020) presented the comparison between Artificial Neural Networks (ANN), Regression

Analysis (RA) and Support Vector Machine (SVM). The performance of different models was evaluated using Mean Absolute Percentage Error (MAPE), with the LR model achieving a MAPE of 4.79%, SVM model achieving a MAPE of 0.30%, and ANN model achieving a MAPE of 0.15%. The SVM model achieved an R^2 of 0.955 (95.5% accuracy), indicating a good level of precision. On the other hand, the ANN model achieved an R^2 of 0.99 (99.9% accuracy), demonstrating an even higher level of accuracy. The evaluation of the models based on MAPE and R^2 values highlights the superiority of the ANN model in terms of accuracy, making it the preferred choice for price prediction in construction projects.

3. SUMMARY

ANNs were found to be well-suited for nonparametric cost estimation, particularly in conceptual or early stage project estimates. The efficacy of ANNs to model cost without assuming functional relationships and their capacity for knowledge generalization were highlighted. Overall, the literature reviews highlight the successful application of ANNs in construction cost estimation, showcasing their accuracy, reliability, and potential for early cost estimation. Optimization of model parameters and architecture, as well as the ability of ANNs to generalize knowledge, were emphasized in enhancing the performance of the models.

4. METHODOLOGY



3.1 ADVANAGES OF USING ANN

- Artificial Neural Networks possess the ability to acquire knowledge of non-linear relationships between variables.
- ANNs exhibit the potential to learn and adjust based on new data, resulting in progressive enhancement of their performance.
- Once trained, ANNs can generalize their knowledge to make predictions on unseen data, thereby offering a versatile platform for predicting unknown features.
- ANNs demonstrate fault tolerance by redistributing responsibilities among active neurons when certain neurons fail to provide a response, ensuring uninterrupted functionality and information processing system.

3.2 LIMITATIONS OF USING ANN

- ANN models are prone to overfitting, which occurs when the model becomes very closely fitted to the training data.
- Obtaining comprehensive and reliable historical cost data can be challenging and time-consuming.
- The models may require periodic updates and retraining as new data becomes available or project characteristics change.

4. CONCLUSIONS

The successful application of ANNs in construction cost prediction showcases their accuracy, reliability, and potential for improving cost estimation practices in the industry enabling more informed decision-making and better project planning. However, it is important to address the limitations of ANNs. By optimizing model parameters, model architecture and addressing these limitations, ANNs can enhance their performance and provide valuable cost estimation tools for construction projects.

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