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STOCHASTIC SOLUTION METHODS FOR CHALLENGES FACED IN PRE-BID STAGE CONSTRUCTION COST ESTIMATION

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ABSTRACT

Present study is on challenges faced by the construction industries in proposal stage and the techniques used to overcome the difficulties faced in planning and construction stages. Financial success of a project depends on the optimal usage of owner's fund. Many methods are proposed by the researchers for prediction of problems in estimating contingency. An attempt is being made to propose the optimal contingency for estimate prepared on construction project so that the estimated cost will be reliable as compared to other techniques used in field. This will result in obtaining better outputs in estimation and costing. The factors affecting the construction project at the proposal stage are analysed and higher weightage is given to variable which has higher influence on the project cost. This prediction technique will act as a gateway for the construction companies to acquire the project since the accuracy of estimation is improved.

Introduction

The main aim of quantity surveyor and cost engineer is to provide a sustainable cost through estimation. The Estimator will always try to make a most likely estimate which is the reflection of reality. Estimating the cost of the project during planning and designing stages is called Pre-Tender cost estimation. Cost estimation prepared at pre-tendering stage is subjected to biases, because they are often prepared within a narrow time frame and without knowing the complete leeway of the project. Underestimation in pre-tender cost estimation may lead to non-feasible project and if accepted by owner and may lead to project miscarriage. Overestimation may lead to rejection of the quoted cost by the owner. The estimated cost of a construction project is influenced by considerable factors such as the structural, architectural and engineering systems. The structural cost holds on area of the construction, amount of material used etc. The architectural cost holds on the design and quality of materials used etc. The engineering system cost consists of sanitary, electrical, air-conditioning and elevator system.

One of the methods for increasing the accuracy of pre-tender cost estimate is to compute contingency reserve by taking in to account of the unforeseen cost. There are many methods for estimating contingency reserve namely Percentage allowance method, Monte Carlo simulation, ANN (Artificial Neural Network), Fuzzy logic and Regression.

Percentage allowance method is most widely used method and this method is based on cost engineers experience and judgment. In linear regression model, the inputs given have linear relationship between them which may not always be appropriate. Another disadvantage is they are not suitable to interact among large number of variables. Regression assumes that affinity between input and the output are linear whereas in construction projects the relation between them is non-linear and sometimes unknown. Multiple linear regressions were developed and found to be useful tool for analyzing and contributes certain additional aspect to the estimate. The disadvantage of Fuzzy approach is that the relationship between output and input variables are decided based on the qualitative information of the project. Artificial Neural Network is non-parametric prediction tool. It is an information processing paradigm and built like a biological nervous system.

Collection of interconnected neurons as a network creates a pattern of inputs to neural network architecture. NN processed as a pattern and results are obtained with pattern recognition techniques. The artificial neuron has been modeled mimicking biological neuron of the human brain. So Artificial Neural Networks (ANN) is a mathematical model that was developed to minimize the error.

PAST STUDIES

Estimating the cost of a construction project with high dependability is one of the challenging tasks faced in the field. Accurate estimation can be achieved by effective use of the available materials. This study is important because large number of construction project results in cost overrun. If the inaccuracies in pre-tender estimate are predicted, then the cost advisors would be able to prepare better cost estimate so that the project owner can be assured of the costs of their projects during the planning and designing stage. Alexander (1994) discussed about the multiplicity concept in construction planning. He explained the importance of plan and what an effective plan would result in. He also commented on the approach of experienced companies on construction and planning of a project. ANN does not assume about the underlying distribution so it is a non-parametric prediction tool. ANN can accept non-linear variable and mathematically defines cost as a function of variable. The important element of ANN is their structure. It has large number of interconnected elements called neurons which work simultaneously to solve a specific problem.

Zuhan Guo, XinlingSun and Yong Wei (2015) used Regression Analysis to improve the accuracy of bid prepared. Bidding decision is a complicated issue. A mathematical statistical analysis method was developed based on the bidding rate and quotation level to understand the process involved in the project. As the result of this case study using regression analysis improved the bidding rate and forecasted certain problems that influenced the projects. This paper determined the reference level and gain rate of bidding by developing a mathematical statistical method, drew the scatter diagram of quotation and success rate. A scientific effective data for bidding projects was also developed

using the linear regression equation of quotation level and success rate by mathematical curve fitting method.

Jason Onpeng(2015) The target of the study is to predict the total structural cost of the building project in Philippines by developing an artificial neural network(ANN). Data from thirty building projects were collected and are classified under six parameters. NN toolbar in MATLAB R2010a was used in constructing the ANN total cost model estimation. These collected data sets were randomly selected in MATLAB to perform training, testing and validation operations. The data were first normalized before training to speed up the training process and to improve the network performance. The Tan-Sigmoid function and Feed-Forward Back-Propagation technique was used to generate the best model to predict the total structural cost. The ANN with six input variables, seven nodes in the hidden layer and one output node was best in predicting the cost. The network predicted the cost to a closer extend when enough training was give.

Hany (2014) considered BPNN (Back-Propagation Neural Network), PNN (Probabilistic Neural Network) , GRNN(Generalized Regression Neural Network) and Regression Analysis. He used MATLAB version 2009. The result obtained from MAPE (Mean Absolute Percentage Error) using PNN showed best performance among all the models. Building Area, Perimeter, Joist span and height was identified as main parameters which were correlated with the fabrication cost of steel structural building.

Mohammed Arafa (2012) constructed a NN with 7 input layers (ground floor, typical floor area, number of storey, number of column, type of footing, and number of rooms) with one hidden layer and 1 output layer. Back-Propagation technique was used to get the output; Used MATLAB version 2009. Tan sigmoid transfer function was used in hidden layers and linear transformation was used in output layer. Study location was Gaza strip. He concluded that Ground Floor area, Number of Elevators, Number of Storey and Type of Foundation had significance influence on the output

Ajibade (2011) proposed a learning algorithm trained by making use of the data from completed projects to allow quantitative and objective estimation. A 3 layer feed-forward neural network was trained to generalize 9 input variables. The method which is widely used in construction estimation is BPNN. Development of high quality BPNN is difficult. The process of developing BPNN requires experimentation. It requires routine refinement of network parameters, network redesign and problem reformation. GRNN when compared to BPNN can learn faster with data sets having limited information. GRNN output result increases as number of sample increases. PNN can learn fast and it can also be further improved when needed. So a comparative analysis of three networks was done and each had certain advantages and dis-advantages.

Irem Dikmen (2004) constructed a ANN model with 16 input criteria and two output nodes to make strategic decision supporting tool that can classify international project based on their attractiveness and the competitiveness of the company. Neural Networks Professional II Plus (2000) software was used. The most important parameters affecting the project attractiveness was found (market volume, availability of fund, country risk and economic prosperity).

Hojjat Adeli and Yeh (2001) presents a model of machine learning engineering design based on the concept of control parameters and perceptron. Perceptron is a supervised learning algorithm with a four-tuple entity (sensors to receive inputs, weights to be multiplied by the sensors, a function

collecting all the weighted data to produce a proper measurement on the impact of the observed phenomenon and a constant threshold). A structural design problem was formulated as a perceptron without hidden units. Applied the model to the design of steel beams and effective results were obtained.

Tarek hegazey and Amr Ayed(1998) used neural network (NN) approach to readjust construction cost data and established a statistical cost-estimating model for highway projects. Eighteen construction project data were collected from Newfoundland, Canada. Simplex optimization and genetic algorithms techniques were used to determine the network weights. The weights that produced the best forecast of cost for the past data were used to find the fittest NN. The best NN was tested on new project by creating handy spreadsheet macros to get faster access for the input and automate cost prediction. Further, sensitivity analysis and adaptation program was also developed to consider the uncertainty of the project and to re-optimize the model on new historical data. A three-layer NN with one output node was simulated in Microsoft Excel spreadsheet. The developments made in this paper demonstrated the practicality of using spreadsheet programs in creating satisfactory NN models for future use in construction field.

Alexandar Laufer, Avaiad Shapira, Dora Cohenca-Zall, Greogory A. Howell (ASCE) (1994) has presented the result of research project that examine the planning done at pre-bid and preconstruction stages. The data was accumulated by professional detailed interview conducted with experienced project managers and other functionaries in reputed construction companies in United States. Data was collected from eight leading companies in western United States. Overall 22 interviews was held out of which 18 was helpful. Results were analyzed at pre-bidding stage. More than 80% of project managers exposed a strong degree of involvement in organization and contracts and 61 to 80% of them relayed in three plans (cash flow, schedules and major equipment available). Pre-construction planning stages last up-to 3 months.

METHODOLOGY

Data collection and Identification of Input Variables

The data from 31 building projects were collected from various construction companies in Tiruchirapalli district, Tamil Nadu. The main documents to be collected are

- Detailed & Abstract Estimate
- Blueprints
- Duration of Completion of the Project
- Payment Details

These data collected were manually crosschecked for eliminating false and odd characteristic building data.

Final Completed Cost of the Project is found by summing Labor Cost, Material Cost, Transportation Cost and Engineer/Designer/Supervisor Charges.

$$\text{Estimate bias} = \frac{\text{pretender cost estimate} - \text{projec completion cost}}{\text{project completion cost}} \text{x} 100$$

Six input variables namely, Number of floors, Building Area, Number of Columns, Project Type, Type of Foundations and Site Access are considered. The collected data are fed into the computer

using a data entry sheet so as the data collected can be organized, recorded, indexed and analyzed. Number of floors ranges from 0 to 6. Project Type is classified into commercial and residential building. Building area ranges from 50 to 3000 square meter. Site access is classified into Free, Restricted and Semi-Restricted area. Number of column ranges from 12-210. Type of foundation used was classified as strip and pad foundation. A total of 31 completed project data were collected from different area within the selected location. Then the collected data is transferred to MS-Excel spreadsheet. The data in the entry sheet are fed into MATLAB software and are evaluated using the NN tool.

Building of NN model

The Neural Network decided to be used are Generalized Regression Neural Network and Back-Propagation Neural Network.

Back-Propagation Neural Network (BPNN)

The number of input neuron created is six. The number of hidden layers was decided based on trial and error method. The weights and bias are added to the hidden layer. The activation function will squash and then variables will have the values between 0 to 1 and -1 to +1. It depends upon the type of activation function used. Here Tan sigmoid activation function is used. Finally one output neuron is created which represents the cost of the project. The 31 construction project data were divided randomly by MATLAB for training, testing and validation purpose and then the trained NN was generated.

Training: The set of data is used for modifying the weights and bias in order to minimize the network error. 60% of data was taken for training.

Validation: Error will be monitored and if the error raises the set limits then the training is stopped and a reasonable level of performance error function will be adapted. 20% of data is used for performing validation check.

Test Sets: Further, the checking and generalization of the Network is done. 20% of data is used as test set.

The BPNN model used is shown in **"**FIGURE1".

Generalized Regression Neural Network (GRNN)

Radial basis network trains the data faster. With the same set of 31 project data, GRNN was generated using MATLAB. Six input neurons were created. Then a layer is developed by GRNN which calculates the distance and bias is calculated and summed. After arriving the distance from the input samples, an exponential activation function is used. The activation function used decides the weights. Denominator neuron will sum all the weights and Numerator neuron will multiply weight and output of each neuron. Output is obtained by dividing numerator and denominator. Thus a single output is generated. The GRNN model used is shown in "FIGURE 2".

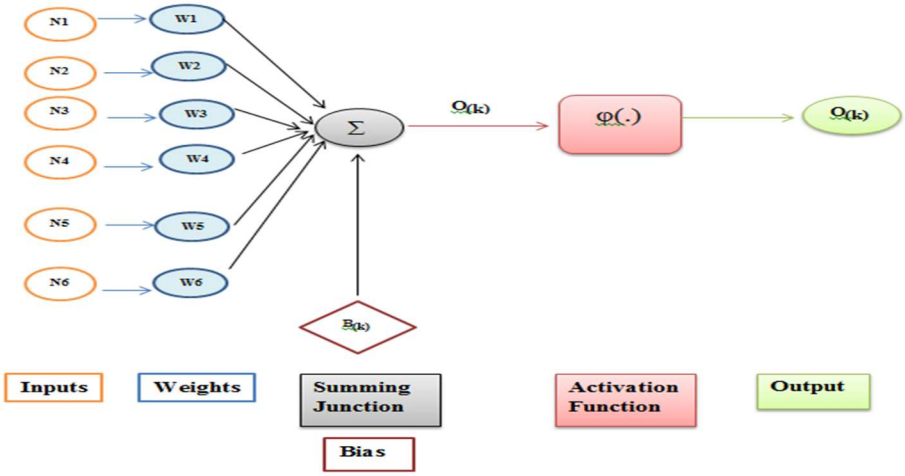


FIGURE 1 BPNN model used

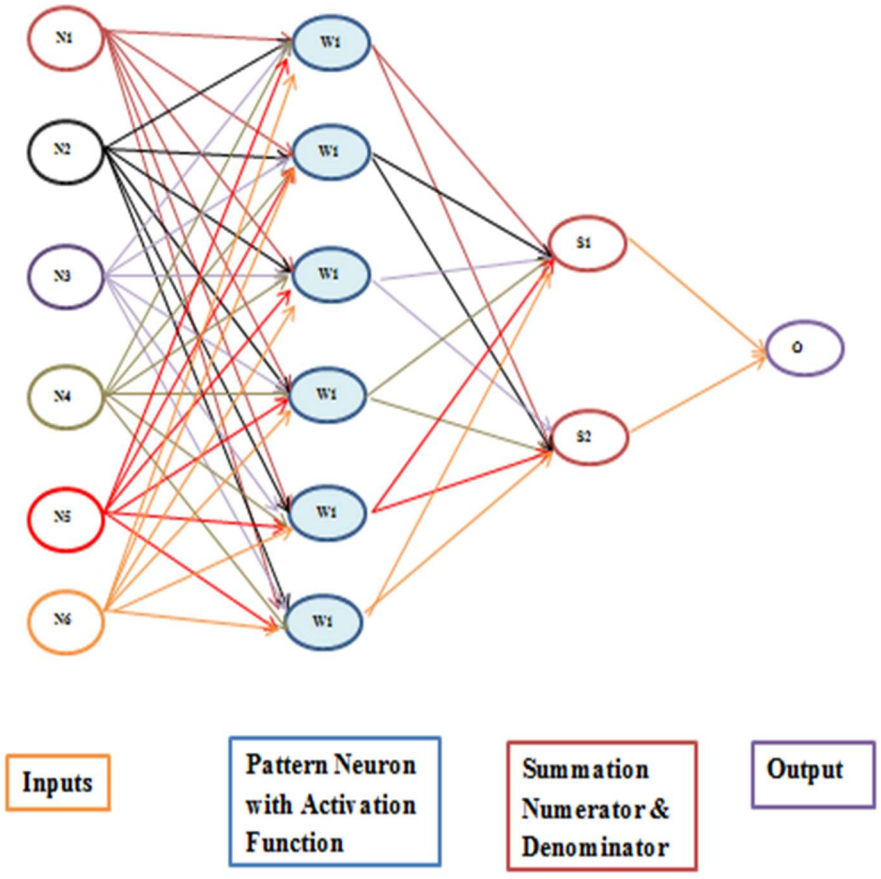
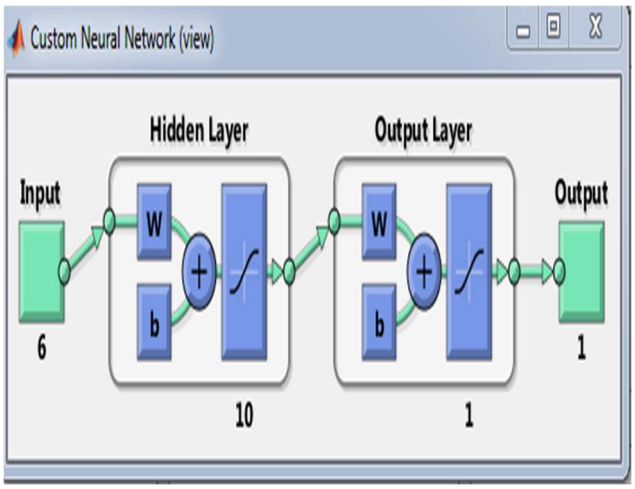


FIGURE 2 GRNN model used

Results and Discussion

Based on the practical interaction with selected Engineers and Contractors, the difference in the estimated and the completed cost is due to following factors.

- Based on the site location and condition
- Labor Cost
- Material cost
- Natural calamities
- Changes in Governmental Laws and Rules



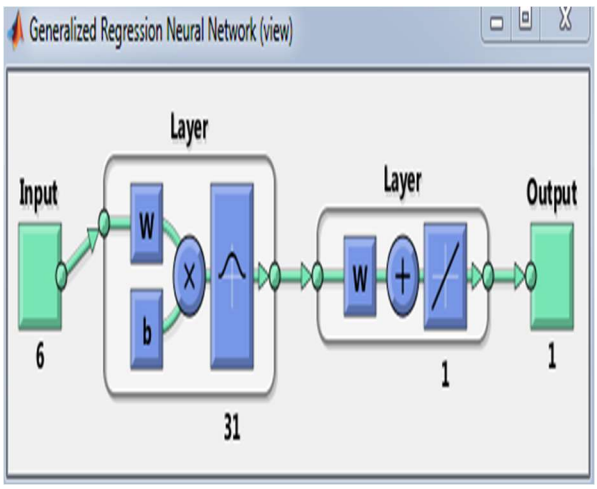


FIGURE 3 BPNN model generated **FIGURE 4 GRNN model generated**

The models of BPNN and GRNN were created using MATLAB R 2014a as shown in "FIGURE 3 and FIGURE 4".

After several trials, NN Structure with 6 input neurons, 10 neurons in the hidden layer, and 1output neuron was found to be the best model to estimate cost of the building for the collected data sets so that network was simulated.

"FIGURE 5" shows the correlation coefficient, R value for the neural network trained using Feed-Forward Back-Propagation network. The R values obtained are 0.9829, 0.9699 and 0.9748 for training, validation and testing phases, respectively. Training values plotted in the graph were well within the actual cost, but there was a deviation from the target data experienced by the NN while performing validation check and testing. Further to improve the weightage allocated, the number of hidden layers was increased but this lead the network to overlearn. The correlation coefficient (R) obtained using BPNN was satisfactory and acceptable.

GRNN trains the network faster as compared with BPNN. "FIGURE 6" is the result generated using GRNN. The graph plotted compares the actual cost with estimated cost and simulated cost. The simulated cost is the cost generated by using GRNN. The cost simulated by GRNN and the actual cost are closer than the estimated cost and the actual cost. Thus the contingency is reduced to

a greater extent. It is concluded that the predictability of GRNN is higher than BPNN for the given data sets.

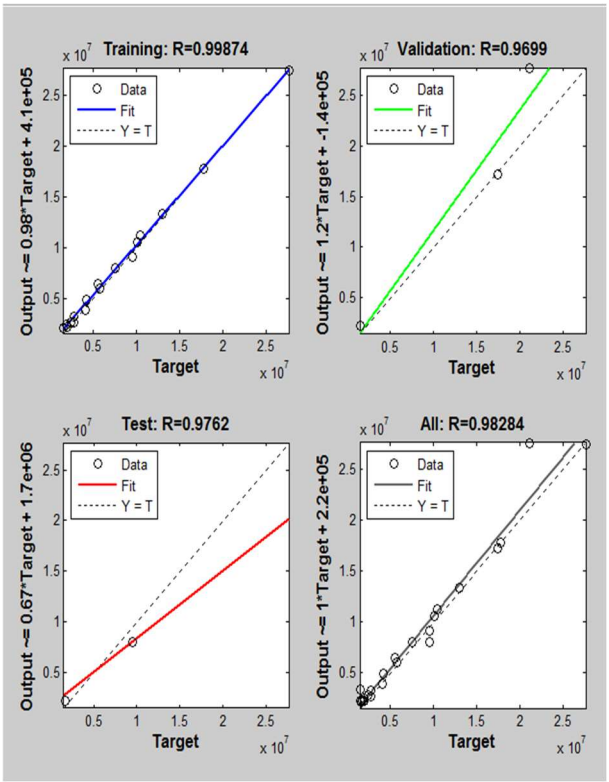


FIGURE 5 Output of BPNN

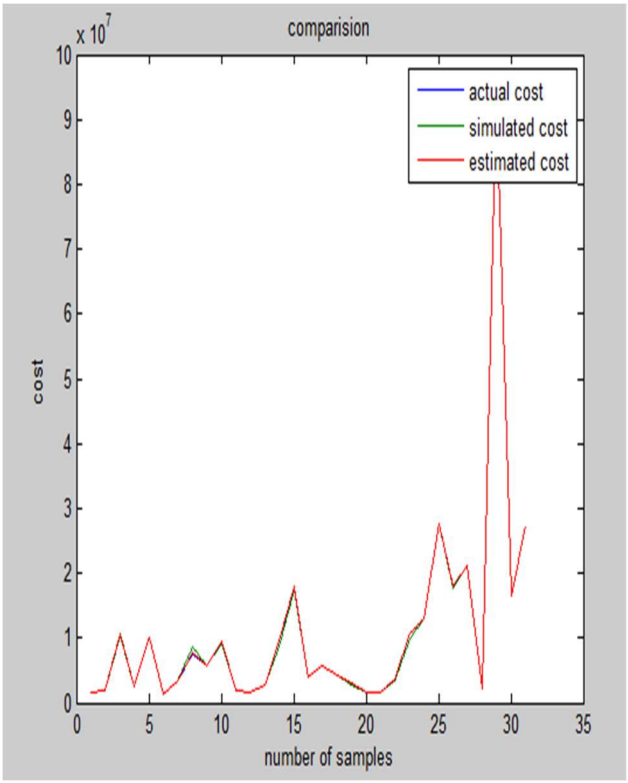


FIGURE 6 Output of GRNN

Different input parameters and different construction industry setting were used. Cultural difference may affect the building construction method, which in turn affects the material cost. Lower R values were showed by the model developed. By using a larger dataset, the model generated in MATLAB can further be improved.

Conclusion

The cost estimation technique available is lacking in reliability and accuracy due to various unstable events and many assumptions that we are forced to make because of the limitation in data and time constraints so a new alternative method is proposed in this work. Even though many methods are used for the prediction of construction cost estimate in various situations, the regression analysis and artificial neural network are said to be the most effective tools. Occasionally ANN is coupled with Fuzzy logic and Genetic algorithms also. In ANN method, the computer is trained to solve problems based on the past data available. Simulation software like MATLAB can be used for applying ANN in various fields of civil engineering. Artificial Neural networks offer a number of advantages and some of them are: requirement of less formal statistical training, ability to implicitly detect complex non-linear relationships between dependent and independent variables, ability to detect all possible interactions between predictor variables and the availability of multiple training algorithms.

The main aim of using ANN is to study the influence of various parameters on the final cost of the construction project by dealing effectively with limited input data within limited time frame and by examining and assigning weightage suitably for the parameters which affect the cost of the construction project adversely.

Thus ANN model can be developed and used in big construction industries so as to improve the standard of estimation which in turn benefits the organization by achieving success in the bidding process among the competitors.

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