

Cost Estimation of Building Projects Using Artificial Neural Network (ANN)

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Abstract: The sole purpose of construction planning management is to reduce the time taken in the completion of project and to complete the project under allocated budget which makes extremely important to know beforehand the expected budget. This study has been undertaken to investigate the key factors affecting the construction of projects and estimation of total construction costs of building projects in India with the help of artificial neural networks (ANN). Twenty six data sets of completed building projects or approved for funding were obtained and processed for training and estimation of total construction costs. Altogether twelve key building construction factors were identified covering areas related to the building materials, building specifications i.e. area of typical floor, number of floors, number of staircases, number of rooms etc. Based on these factors, for estimation of total construction costs of building projects, a model was established. MATLAB software was used to train the network and NEURAL DESIGNER software was used to test the reliability of ANN in estimation of total construction costs. The best network was found to having architecture of 12-7-1. The network can forecast construction costs for building projects at pre-construction stage having an accuracy of coefficient of correlation (R) of 99.71% and a mean absolute percentage error of 2.34%. The average accuracy percentage of 97.66% was achieved.

Index Terms– Building Construction Projects, Cost Factors, Cost Estimation, Total Construction Costs, Artificial Neural Network (ANN).

I. INTRODUCTION

Construction planning is the specific process construction managers use to lay out how they will manage and implement a construction project, from designing the structure to ordering materials to deploying workers and subcontractors to complete various tasks. The sole purpose of construction planning management is to reduce the time taken in the completion of project and to complete the project under allocated budget. So it is very useful for knowing the expected budget of the upcoming project beforehand.

As in the estimation of building project's total construction cost, choices of appropriate technology and methods for construction are often ill-structured yet critical ingredients in the success of the project. For example, a decision whether to go for conventional estimation technique or to try new software based technique using Artificial Intelligence. A decision between these alternatives should consider the time taken by the processes to give the result as well as the accuracy. Unfortunately, the exact implications of different methods depend upon various considerations for which information may be sketchy during the planning phase, such as the experience and expertise of workers or the specific underground condition at a site.

II. ARTIFICIAL INTELLIGENCE IN CIVIL ENGINEERING

Artificial intelligence is a multi-disciplinary field which has been created because of the requirement to a deeper study of the possibility to generate human behaviors. A system created based on artificial intelligence must be able to store information, to implement these information to resolve problems and learn new information through experiences.

The brain learns from experiences. In studies so far, it shows that the brain store the information as models. A neural network is an artificial representation of the human brain that tries to imitate his learning process. The term "artificial" means that the neural networks are implemented in computer programs that are able to handle many values for the calculations required along the learning process. This area does not use traditional programming but involves massively parallel networking and training of these networks to solve specific problems. In comparison to traditional computing systems based on neural networks learn examples, they have a distributed associative memory, have a high tolerance for errors, recognize patterns and have greater synthetic capacity. As per 2nd international conference for PhD students in civil engineering and architecture, Pandelea et al. gave a brief description about Neural Networks application in the field of engineering, stated; study the behavior of building materials, structural engineering, structural identification and control problem, heat transfer problems in civil engineering, geotechnical engineering, transportation, construction technology and management, building services issues.

III. THE IDEA BEHIND ARTIFICIAL NEURAL NETWORK

The idea of artificial neural network is based on the belief that working of human brain by making the right connection can be imitated using silicon and wires as living neurons and dendrites.

The human brain is composed of approximate 100 billion cells which are known as neurons. They are connected to other thousand cells by axons. Stimuli from external environment or inputs from sensory organs are accepted by dendrites. These inputs create electric impulses, which quickly travel through the neural network. A neuron can then send the message to other neuron to handle the issue or does not send it forward. The human neural system working is shown below.

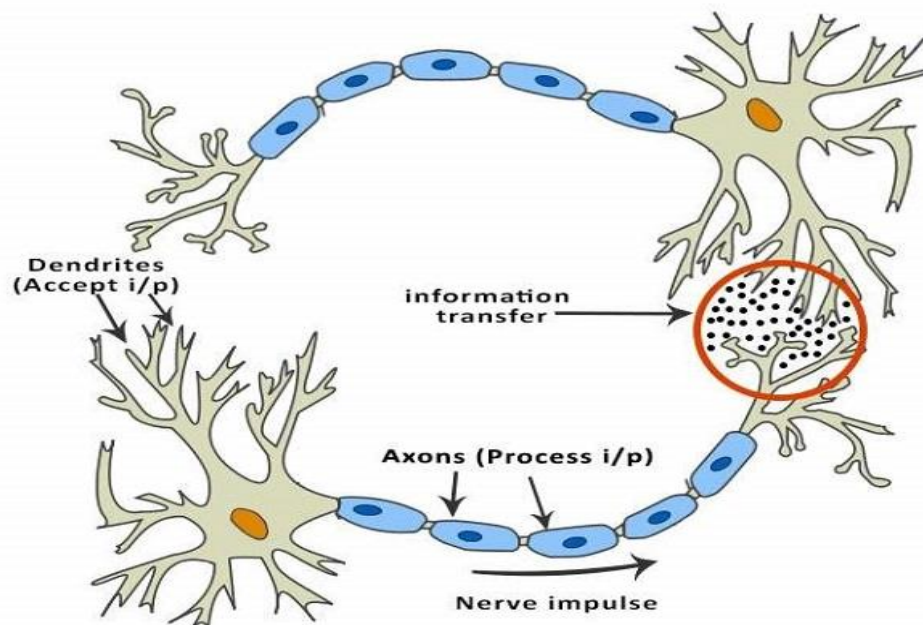


Fig 3.1 Biological Neuron

IV. STRUCTURE OF ARTIFICIAL NEURAL NETWORK

The basic structure of an artificial neural network consists of artificial neurons (similar to biological neurons in the human brain) that are grouped into layers. The most basic artificial neural network structure consists of an input layer, one or more hidden layers and an output layer. Positive weights activate the neuron while negative weights inhibit it.

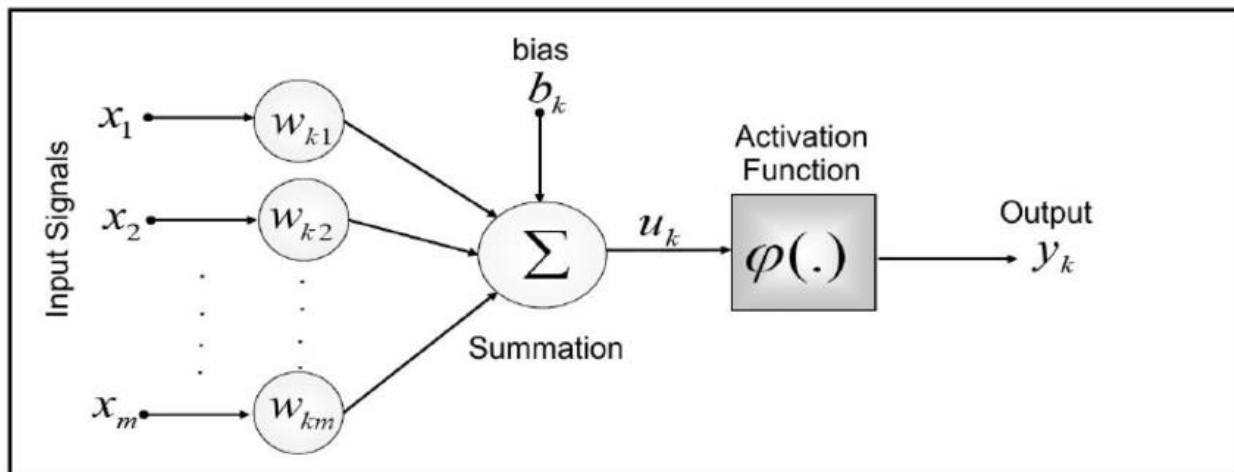


Fig. 4.1 Structure of artificial Neural Network

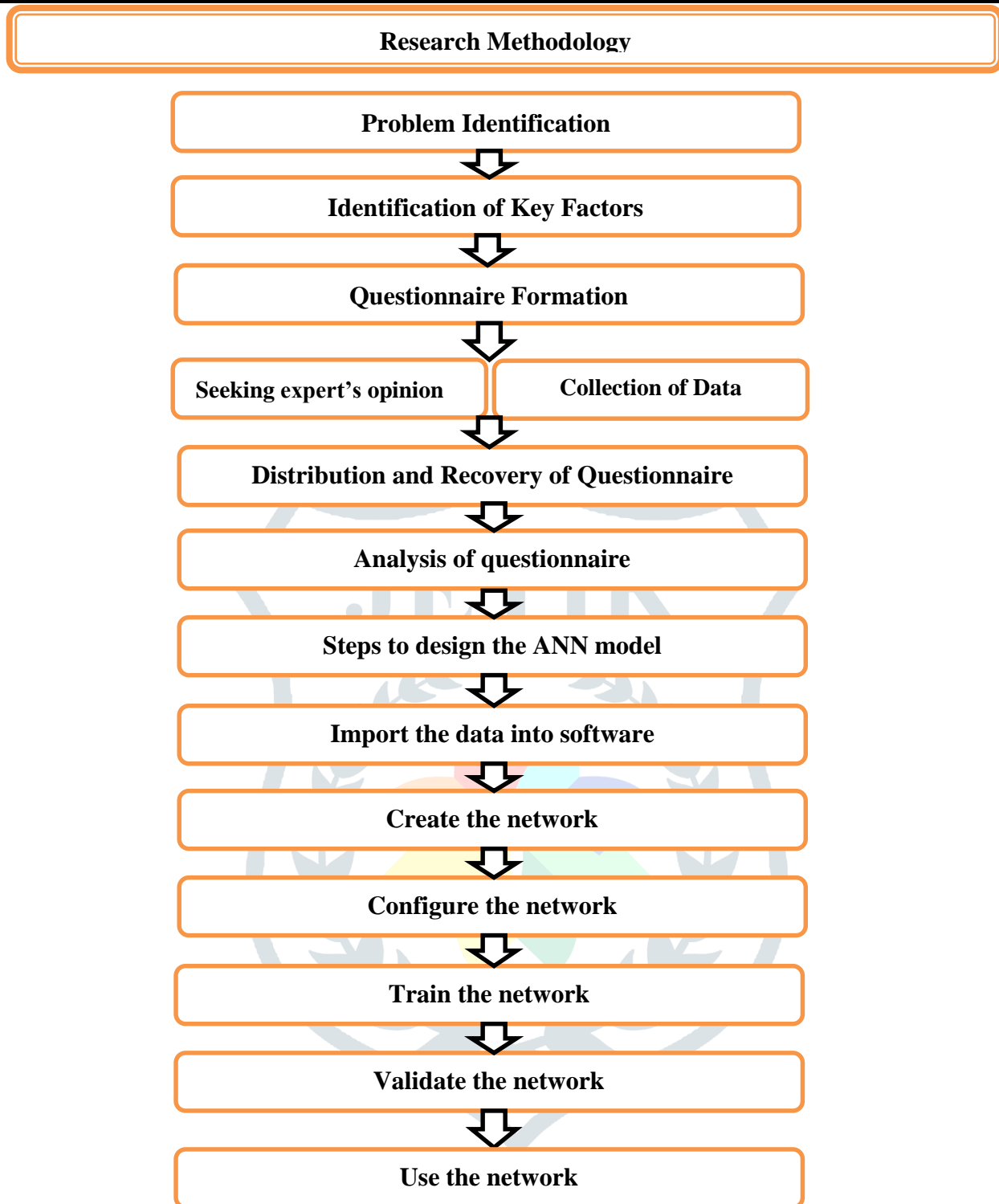
V. TYPES OF MACHINE LEARNING

- **Supervised learning method:** The network is delivered with number of layers, the number of neurons per layer of the network and the type of activation function used, and the synaptic weights, and then the network adjusts the weights after comparing the results from the network with the output to minimize the error.
- **Unsupervised learning method:** The target output is not offered to the network. Thus, the network trails a self-supervised method and makes no use of external influences for synaptic weight modification.
- **Reinforcement learning method:** The network is not provided with the output but it is learned if the output is a good fit or not.

VI. ANN METHODOLOGY

This chapter included information about the Identification of key factors, Questionnaire formation, Analysis of questionnaire and ANN model for total construction cost. The important information and required projects data are collected on two stages which are: -

1. Comparison between the list of total construction cost factors collected from the previous literature, via a review study phase, and the applied total construction cost assessment, from the opinions of site engineers,
2. Collection of the required total construction cost data for a number of building projects in India to be used during the analysis phase and the design of a total construction cost assessment model. The selected methodology to complete this research is shown in the flowchart below:



Problem identification was the first step of the research included in the thesis proposal which include identifying and defining the problem which was followed by the second step of the research which involved reading and appraising what other researchers have written about the subject area and identification of key factors influencing the total construction costs of building projects. This step is to make a comparison between the total construction cost factors from the comprehensive literature study and the Indian construction industry for the identification of total construction cost factors for building construction projects, in India. Questionnaire formation was the third step which is divided into two integrated steps, first step is seeking academics opinion for developing the questionnaire and second step is to collect the data from different projects. A structured questionnaire has been applied in this research for expert's advantages. Expert's Opinion is the most significant step of this research methodology, as it includes a detailed evaluation of the developed list for total construction cost factors in building construction projects and making the required alterations on it in order to create it fit to be used during the origination of the neural network model.

There are so many factors that affect the construction cost of building projects, some of which are direct and some of which are indirect. After analyzing the previous work done in this field, 12 factors has been identified as input variables for our study, which are: area of typical floor, number of floors in the building, number of elevators in the building, number of staircases in the building, years of construction, height of the floor, working time hours, number of rooms, cement price, steel price, sand price, aggregate price. Most of the variables which have been selected are real figures.

Developing Questionnaire is the next step of our research. Forming perfect design of the research questionnaire is crucial to get precise results of the work. Therefore, the questions were designed to be specific, realistic and measurable. After the factors are identified for our research purposes, the work of the software starts. In order to design the artificial neural network model, we used MATLAB and NEURAL DESIGNER software.

The steps for designing the artificial neural network are as follows:

- Collection of data
- Create the neural network
- Configure the neural network
- Initialize the weights and biases
- Train the neural network
- Validate the neural network
- Use the neural network

VII. DATA COLLECTION

Total 26 questionnaires have been collected for the data to be further processed. The collected data has been made more systematic for the use in software. Area of typical floor and height of the floor are square feet and feet respectively. No. of floors in the building, no. of elevators in the building, no. of staircases in the building and no. of rooms are unit less variables. Years of construction has been taken in months. Direct cost related variables such as cement price, steel price, sand price and aggregate price have been taken in rupees per ton.

In fact, the process of collecting information that is related to cost estimation problems is a challenging task especially in India, because such information are the property of each construction firm. Construction firms usually do not agree to share their cost related data with others for remaining more competitive in the market. However, great effort and time were exposed to collect sufficient amount of building projects to establish a truthful neural network model. The methodology for collection of these data was based on personal contacts with construction firms.

VIII. DATA RESULTS

In this section, a detailed analysis of collected data and data results will be presented and elaborated by using frequency analysis. The data used in this study was collected from construction firms, collected projects remains 26.

The frequency of data collected:

Table 8.1 Type of project

PROJECT TYPE	NUMBERS OF PROJECTS	Percentage (%)
Residential	16	61.54%
Commercial	5	19.23%
Industrial	5	19.23%
Total	26	100%

The cost related real figures are discussed below:

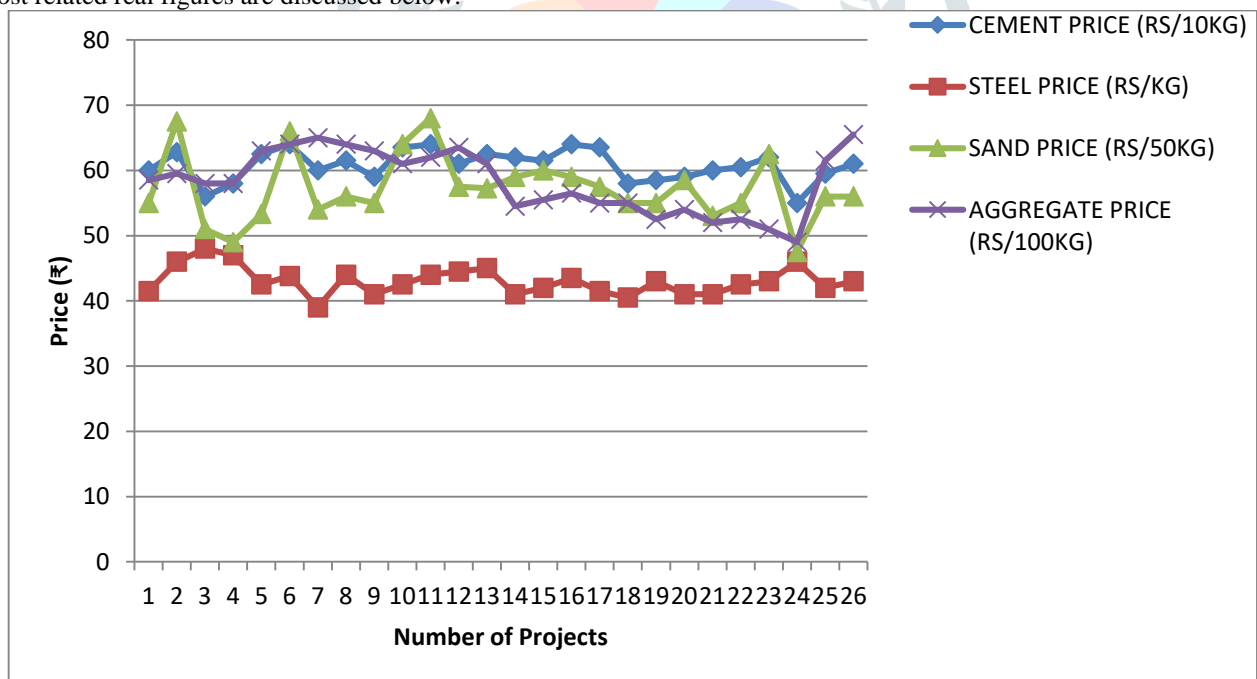


Fig. 8.2 Prices of cement, steel, sand and aggregate

For this research work, MATLAB has been used. A neural network model having 12-7-1 structure has been developed in the software by using Levenberg-Marquardt training rate. Mean square error is the criteria which dictate the performance of the predicted model. The best performance of the model has been observed in the mean square error for trained model as 9.20e-013.

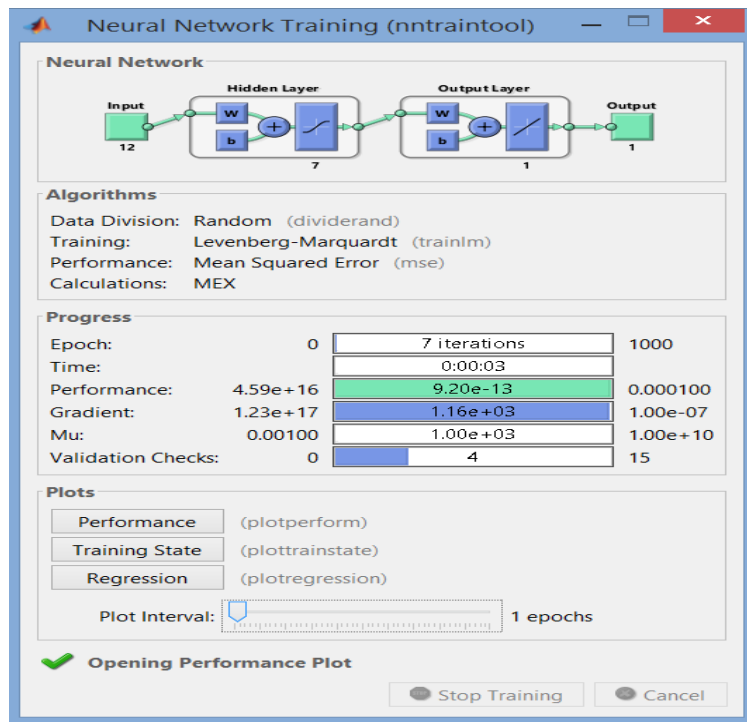


Fig. 8.3 MATLAB performance for trained model

For our trained model 12-7-1, best validation performance we got is 0.33538 achieved at epoch 3.

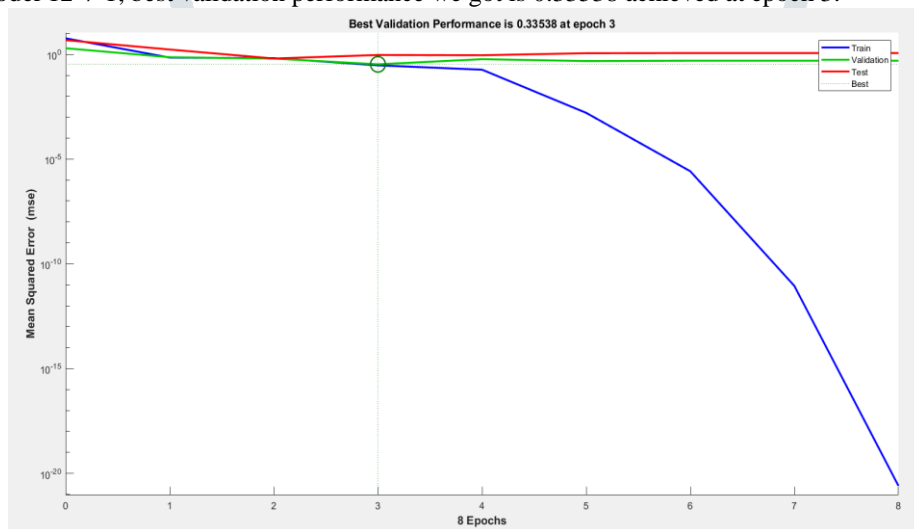


Fig. 8.4 Best validation performance graph generated in MATLAB

An R^2 of 1 indicates us the regression perfectly fit of the data, and the value near to it shows that the prepared model is a goof fit which is case in our work. The target value of R^2 shows value of 0.99414, which is very near to 1 and indicates it is a good fit. R is the slope in the linear fit.

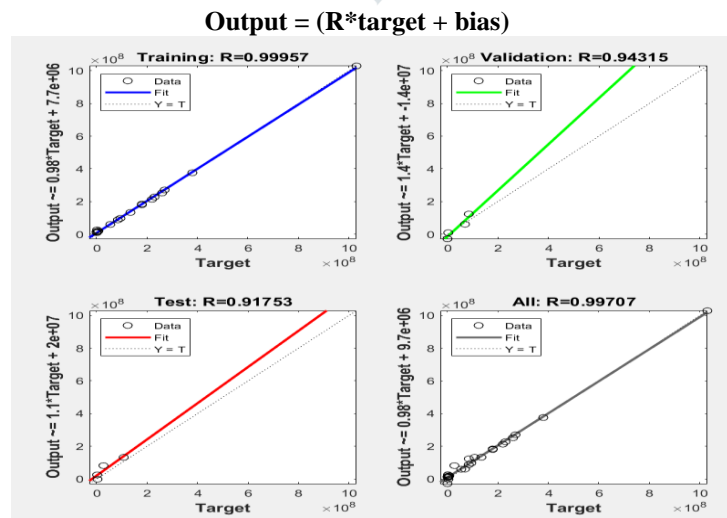


Fig. 8.5 MATLAB regression plot

The model which came as best is shown below:

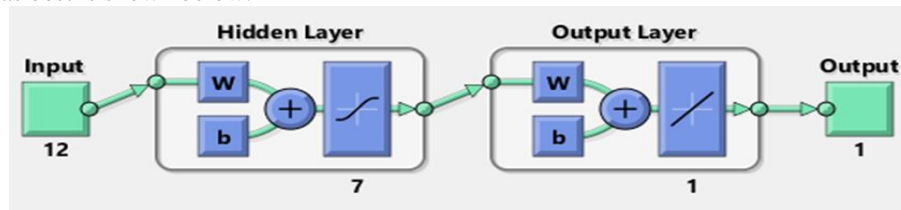


Fig. 8.6 Best architecture model 12-7-1

IX. CHARACTERISTICS OF THE BEST MODEL:

Table 9.1 Characteristics of the best model

Model	Number of input nodes	Number of hidden layers	Number of nodes in hidden layer	LR	TF	Number of output nodes	RMS
Neural network 1	12	1	7	Back propagation	Sigmoid function	1	9.20e-013

After the error calculation from the MATLAB, NEURAL DESIGNER software has been used in order to the prediction of construction costs of building projects.

X. TESTING OF THE MODEL:

This study adopted 3 relative measures of accuracy dealing with percentage errors to compare the forecasting results of the neural network model. Those measures are as follows:

- Percentage error (PE):

$$PE_t = \frac{X_t - F_t}{X_t} * 100\%$$

Where X_t is the actual value of the project t , and F_t is the forecast value of the project t .

- Mean percentage error (MPE):

$$MPE = \sum_{i=1}^n \frac{PE_i}{n}$$

Where n is the number of forecasts

- Mean absolute percentage error (MAPE):

$$MAPE = \sum_{i=1}^n \frac{|PE_i|}{n}$$

Table 10.1 Prediction results of two real case building projects

PROJECT	PREDICTION RESULTS OF CONSTRUCTION COSTS BY NEURAL DESIGNER	ACTUAL CONSTRUCTION COSTS	PE	MPE	MAPE	AVERAGE ACCURACY
1	₹ 13,23,84,800/-	₹ 13,50,00,000/-	1.937%	-0.40%	2.34%	97.66 %
2	₹ 56,50,593/-	₹ 55,00,000/-	-2.738%			

$$Relative \% error = \frac{(Real\ life\ value - Predicted\ value)}{Real\ life\ value} * 100$$

- Assessment of the model:

Table 10.2 assessment of the model

Project number	Model prediction	Real life value	Relative error	Assessment
1	₹ 13,23,84,800/-	₹ 13,50,00,000	1.937%	Accepted
2	₹ 56,50,593%	55,00,000/-	-2.738%	Accepted

XI. RESULT AND DISCUSSION:

The analysis of the network model created by NEURAL DESIGNER illustrated that height of the floor, area of typical floor, number of rooms, cement price, steel price, sand price and aggregate price are identified as the top 7 factors that affect the total construction costs of the building projects. Number of floors in the building, number of elevators in the building, number of staircases in the building, Years of construction, and working time hours are the lowest affecting factors in the estimation of total construction costs of building projects in India. ANN structure 12-7-1 was chosen as the best architecture with the highest correlation coefficient value and lowest MSE value. The result of testing for the best model indicated a mean square error value of

9.20e-013 and mean absolute percentage error value as 2.34%. Testing was carried out on two new projects that were still unseen by the network. The results of the testing indicated an accuracy of 97.66%.

Table 11.1 Results of the ANN model

Description	End results of ANN model
MAPE	2.34%
AA	97.66%
R	99.7%
R ²	99.4%

Where AA = average accuracy%, R = the coefficient of correlation, R² = the coefficient of determination

XII. REFERENCES

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