# The Automated Cost Estimation in Construction

**Mohammad Kabir Yaqubi, Sandeep Salhotra**

***Abstract*: *The importance of decision-making in cost estimation for the building design process signifies the requirement for both designers and project managers. This article examines the usefulness of neural network methodology to address costs assessment at early stages of building design. The data is collected from 10 educational projects constructed in India. An automatic cost estimation GUI is prepared in MATLAB simulator to calculate the total cost of a construction project. Artificial intelligence is used to train the system on the basis of the data collected from 10 different projects and cost has been analyzed with higher accuracy. From the experiment it is observed that the use of artificial neural network helps the project participants to analyze total cost in a very small time.***

***Keywords*: *Automated Cost Estimation, Educational Projects, Built Up Area, Ground Coverage Area, Utilities, ANN.***

## I. INTRODUCTION

Automated cost estimation is also known as pre-designed cost estimates that are prepared before the starting of any construction project such as before the construction drawing preparation as well as specifications. In this phase, the company owner, contractor, designer or loan organization needs to make cost estimates for a variety of purposes, such as to determine the project feasibility, conducting a financial assessment of several alternative projects, or establishing the budget at the initial phase [1]. Automated cost estimates are not anticipated to be accurate as the scope of the project has not yet been finalized and also very few design information is presented during the pre-design phase of the project. However, based on the available information, fast, inexpensive, and reasonably accurate estimates are needed. To overcome this problem cost management process is required. This process needs a large amount of processing information in a well-timed manner [2]. This article focused on estimates cost automatically by utilizing the concept of neural network. To help in the decision-making procedure, automated cost estimates are typically generated at the front end of the building project development. However, the highly unstructured nature of these estimates may raise some concerns in the industry. Personal estimation experience and different estimation practices may agree to produce conflict and consequently unreliable cost estimates [3]. This difficulty has been reinforced in the cost estimate of low-rise buildings. A number of techniques for automated cost estimation have been proposed. Regression analysis, simulation and neural network are used to optimize the cost estimation of building construction that is used in the early project phase [4].

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The development of software technologies has assists the progress of new techniques to cost estimation. With the advent of artificial intelligence (AI) mechanism such as neural networks, it is now possible to study possible multilinear and nonlinear relationships [5]. The results of methods demonstrated that the use of new technologies is more practical and accurate than real-life conditions. From the existing survey, the material selection and the building design have a significant impact on the cost of constructing a building. In general, as the building cost comprises of various items such as cost of constructing walls, doors, windows and the finishing and renovations. cost. Depending on the type and use of the building, the relative weight of these projects will vary from project to project [6], and cost estimates might be required an improved multidisciplinary collaboration.

In 2002, the researchers Olotuah and A. O [7] has been examined that the building cost material is approximately equal to 60 % of the cost of building. For multistory residential building, the foundation cover cost up to 25 % of the entire building construction cost has been examined by Gould, F. E in 2000 [8]. The purpose of this research is to design an analyze a building model that optimized the cost automatically by utilizing artificial neural network structure.

ANN model facilitates the developer to take knowledgeable decisions at the initial stage of the construction process. It should be noted that using artificial neural network models, even if there is not enough information in the early stages of the design process, practically accurate predictions can be obtained. This approach encourages the feedback process and helps designers to achieve the best solution of the assigned problem [9].

## II. RELATED WORK

Hola et al. (2010, 10) presented a mechanism to find out the execution time as well as cost of earthworks. ANN structure has been used to find out the productivity of the selected machine group. The feedforward multi-layer back propagation neural network has been utilized in addition to conjugate gradient algorithm (BPNN-CGB). The presented ANN comprises of the input layer having 5 numbers of neurons, the hidden layer has 8 neurons, and the output layer has 1 neuron, which can be used to predict the mechanical set. The productivity of the work has been composed of c excavators along with N transport vehicles.

Kim et al. (2004, 11) proposed back propagation neural network with genetic algorithm for the cost estimation. The input parameters of the backpropagation neural network such as gross floor area, story's, duration roof type etc have been optimized by genetic algorithm. From the experiment, it has been concluded that with the increase in the hidden layer the accuracy of the cost

estimation system has been decreased.

Wang and X. J [12] in 2018 have presented a new approach to determine project cost with higher accuracy. The presented work has divided mainly into three types named as construction cost, structure cost and outdoor engineering cost. The backpropagation neural network has been utilized to forecast the cost of construction cost and also reduce the mean square error.

Juszczyk and M. (2019, 13) presented support vector machine to optimize the problem of regression in the field of construction. Training data for SVM is the features of the building and structural members that are related the floor structural frame and outputs representing respective actual cost estimates for the floor structural frame. The results obtained from the experiment allow the cost to be predicted with acceptable accuracy.

Juszczyk et al. (2018,14) presented their survey of the applicability of artificial neural networks in estimating the total cost of stadium construction. The study allows authors to make assumptions about the general applicability of MLP-type networks, which may map the relationship between the total cost of construction engineering and the selected cost predictor of the stadium's characteristics.

## III. NEURAL NETWORK

Presently, neural network is an evolutionary version of the learning algorithm proposed by McCulloch and Pitts in 1943 to solve the challenging mathematical problems. In this work, we are using fee forward neural network with back propagation network. A general structure of feed forward back propagation neural network is illustrated in figure 1.

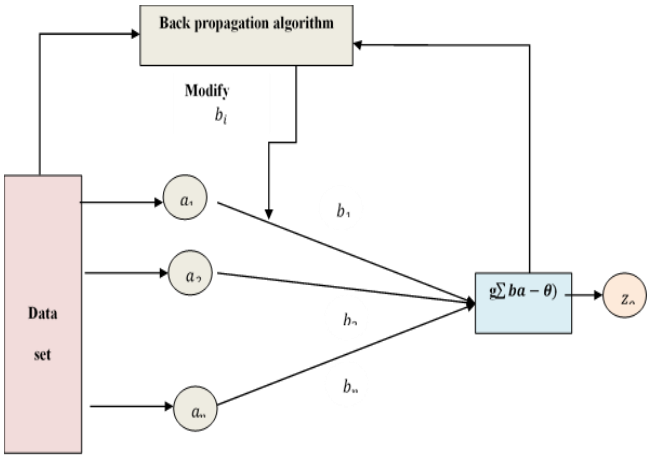


**Fig.1** Artificial neural network (ANN)

Figure 1 represents the simplest structure of feed forward back propagation neural network with single layer. Here, there are n number of inputs $(a_1, a_2, \ldots . a_n)$ with an individual neuron at the output layer represented by $z_o$ . The input data is reached at the output layer through the n number of interconnections each comprises of a n number of weights denoted by $(w_1, w_2, \ldots . w_n)$. As per the guidelines, hidden nodes are calculated as per the following equation:

$$Min\ hidden\ nodes = \frac{\sum Number\ of\ input\ nodes\ (6) + Output\ nodes}{2}$$

In the proposed work six numbers of input nodes with single output node is used. There are two mathematical functions performed by the neural network represented by g(.) , which is a activation function, $\theta$ is the threshold that utilized to determine the value of product ab which is smaller than that of ab product. The activation function used in this research is linear. Every neuron in the hidden layer added the input data after multiplying weight with the data. The formula used is written below.

$$Output = w_1 * a_1 + w_2 * a_2 + w_3 * a_3 + \cdots + w_n * a_n$$

Where, n is the count of input data, w is the weight with a as a input data. The weight is adjusted as per the following steps:

- Initially the weight is assigned with smaller random number.
- The steps are repeated until the ANN structure is trained.
- TO train the network, every input node receives the input data and forwarded data to the hidden layer.
- In hidden layer the weight units are summed up as per the following equation

$$Ativation\ Function = (w_1 * x_1 + w_2 * x_2 + w_3 * x_3 + \cdots + w_n * x_n) + B_1 + B_2 + B_3 + \cdots + B_n$$

B Bias added with each weight

$$Activation\ function = \sum_{i=1}^{n} w_i * x_i + \sum_{i=1}^{n} B_i$$

The value of weight (w) are distributed randomly to the interconnection at the initial stage, and later on modified by using back propagation neural network or through the training process. The output value generated after applying ANN obtained is compared with the initial value and the error generate is again fed back to the input layer through backpropagation. This process is repeated until the error generated at the output layer is minimized up to the desired level.

Also during the testing process, the efficiency of ANN has been analyzed as per the MSE and RMSE equations.

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(Cost_{Predicted} - Cost_{Actual})$$

Or

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(Cost_{Predicted} - Cost_{Actual})^2}$$

### 3.1 NEURAL NETWORK BASED COST MODEL

The structure of neural network of proposed work for cost estimation in educational building projects is shown below.

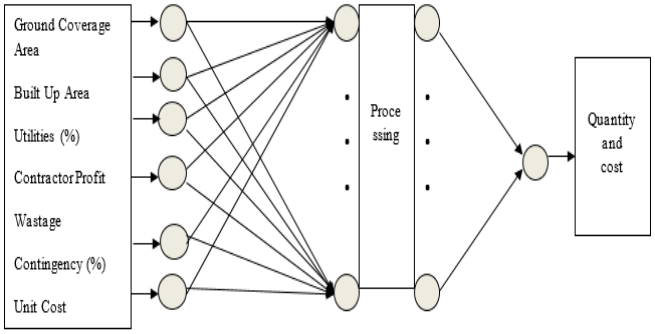


**Fig.2** ANN for estimated cost

Figure 2, comprises of three layers input, hidden and output layer. The input layer comprises of seven numbers of inputs such as: Ground Coverage Area, Built Up Area, Utilities (%), Contractor Profit, Wastage, Contingency (%) and unit cost. In processing unit the cost has been estimated based on unit cost and quantities of materials. The out has been obtained at the output layer of ANN in terms of total cost.

## IV. METHODOLOGY

The aim of this research is to design a cost estimation model using ANN that helps to predict the final cost of the project. The ANN is trained as per the historical data collected from previous education projects. The ANN is trained as per the values such as Ground Coverage Area, Built Up Area, Utilities (%), Contractor Profit, Wastage, Contingency (%) and unit cost. The work has been conducted into three phases: Research strategy, data collection and data implementation.

### 4.1 Research strategy

i. Theoretical study: The related work performed by number of authors to estimating the cost using ANN techniques has been studied.

ii. Field work:

It requires the following steps:

- To analyze the various factors that influence the building cost during the construction process.
- Pilot study has been performed to utilize the engineer's reviews in order to modify and enhance the quality of project.

iii. ANN model has been design to determine the cost of building projects in MATLAB simulation tool.

iv. Validate the cost using ANN structure.

### 4.2 Historical data collection

On the basis of methodology as described above, the cost influencing parameters are determined, data to train and test ANN structure has also been collected. The trained ANN data has been gathered from real life educational projects. Proprietary data (drawings and BOQs) obtained from Chandigarh University, INGOs and construction companies which implemented in educational building sector. This data will provide a rich source of information and past experience to be used in the following stages as training.

Each project must have a cost estimate and actual budget with time scheduling in defined specifications of the project. This detailed data is very useful in determined the factors and the artificial neural network is a probabilistic technique in which several independent variables are used to calculate some dependent variable of interest.

## V. RESULT AND ANALYSIS

The cost of 10 numbers of educational projects is determined using a well-known tool MATLAB. MATLAB (matrix laboratory) is a multi-paradigmatic numerical computing environment developed by MathWorks. MATLAB allows the user to manipulate data in the form of a matrix, plot data in graphical form, apply algorithm such as artificial intelligence technique to the design project and also interface with C, C++ language. The results obtained for the proposed work are described below.

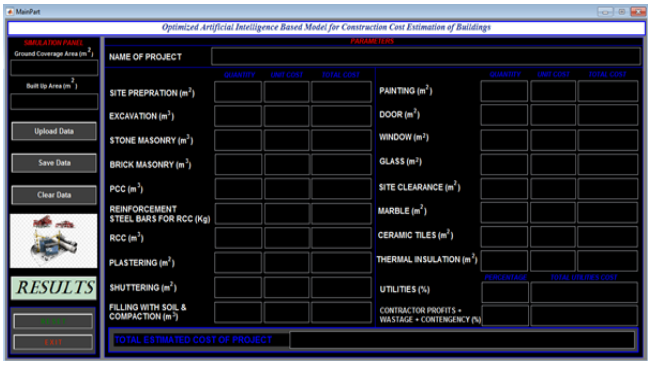


**Fig.3** Proposed Framework of Construction Cost Estimation of Buildings

The proposed framework of construction cost estimation of buildings is given in the above figure. The proposed framework is used to calculate the total estimated cost of the project according to their calculated cost. Above figure is designed under the GUI of Matlab software to estimate the construction cost of the buildings. In the figure, there are three sections named as simulation panel, data entry panel and results panel. The separated panels of the proposed framework are marked in the below figure like red green and blue for simulation panel, data entry panel and results panel respectively.

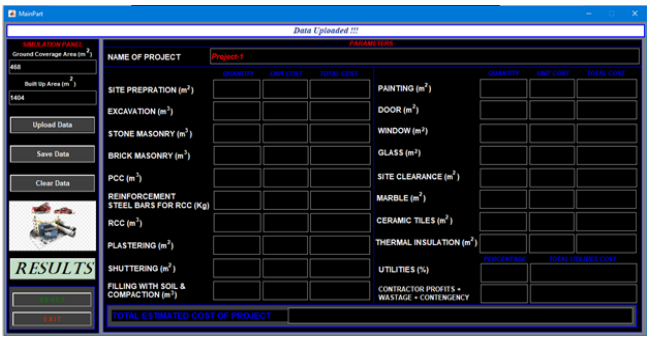


**Fig.4** Uploaded Data

The uploaded test data for project-1 is shown in figure

4. For project-1 ground coverage area and built up area are 468m2 and 1404 square meter respectively. After clicking on Upload button the values are enters.

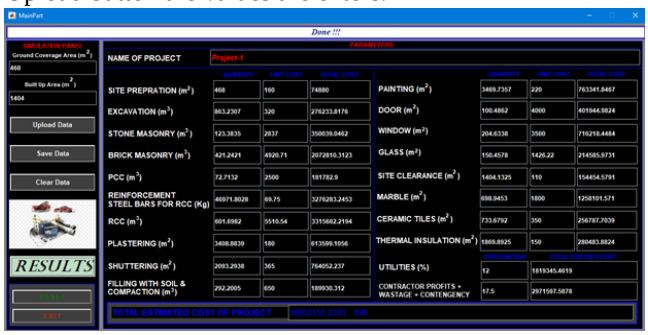

**Fig.5** Result of project-1

The next process is to analyze the results. For this we have to click on "Result" Button and the values of quantities required for the construction of work automatically displayed on the screen. For project-1, the total estimated cost obtained is about 19952155.2321 INR.

**Fig.6** Saved Data

The resultant values are stored into the excel sheet as depicted in figure 6. For saving the data, we have to click on save data button.

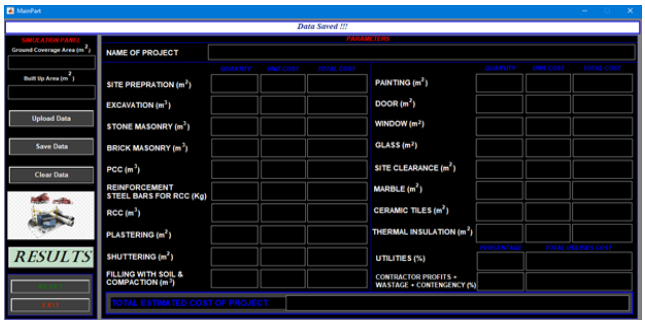

**Fig.7** Clear Data

Now, if we want to proceed for next project calculation, the earliest data is cleared by using clear button as shown in figure 7. The ground coverage area and built up area is listed in table 1.

**Table.1** Simulation of Proposed work with project-1 consider as a sample

| **Project-1** | | | |
|---|---|---|---|
| **Items** | **Quantity** | **Unit Cost** | **Total Cost** |
| Site Preparation | 468 | 160 | 74880 |
| Excavation | 863.2307 | 320 | 276233.8176 |
| Stone Masonry | 123.3835 | 2837 | 350039.0462 |
| Brick Masonry | 421.2421 | 4920.7 | 2072810.312 |
| | | 0 | 3 |
| PCC | 72.7132 | 2500 | 181782.9 |
| Reinforcement Steel Bar for RCC | 46971.8028 | 69.75 | 3276283.2453 |
| RCC | 601.6982 | 5510.50 | 3315682.2194 |
| Plastering | 3408.8839 | 180 | 613599.1056 |
| Shuttering | 2093.2938 | 365 | 764052.237 |
| Filling with Soil & Compaction | 292.2005 | 650 | 189930.312 |
| Painting | 3469.7357 | 220 | 763341.8467 |
| Door | 100.4862 | 4000 | 401944.9824 |
| Window | 204.6338 | 3500 | 716218.4484 |
| Glass | 150.4578 | 1426.20 | 214585.9731 |
| Site Clearance | 1404.1325 | 110 | 154454.5791 |
| Marble | 698.9453 | 1800 | 1258101.571 |
| Ceramic Tiles | 733.6792 | 350 | 256787.7039 |
| Thermal Insulation | 1869.8925 | 150 | 280483.8824 |
| Utilities | 12.00 | % | 1819345.4619 |
| Contractor Profits + Wastage + Contingency | 17.50 | % | 2971597.5878 |

Based on the above table as sample of simulation model we calculate the total cost of 10 different projects which are given in the below table 2.

**Table.2** Project Area

| **Project Name** | **Ground Coverage Area** | **Built Up Area** | **Estimated Cost** |
|---|---|---|---|
| Project 1 | 468 | 1404 | 19952155.23 |
| Project 2 | 1060 | 2862 | 40937304.77 |
| Project 3 | 1200 | 2400 | 35108526.43 |
| Project 4 | 721.5 | 3755.4159 | 52039195.69 |
| Project 5 | 1500 | 10500 | 144203445.3 |
| Project 6 | 1258.24 | 6291.2 | 87302001.3 |
| Project 7 | 1068 | 2136 | 31246588.52 |
| Project 8 | 757 | 1514 | 22147628.76 |
| Project 9 | 1188 | 5940 | 82428453.67 |
| Project 10 | 580 | 4060 | 55758665.51 |



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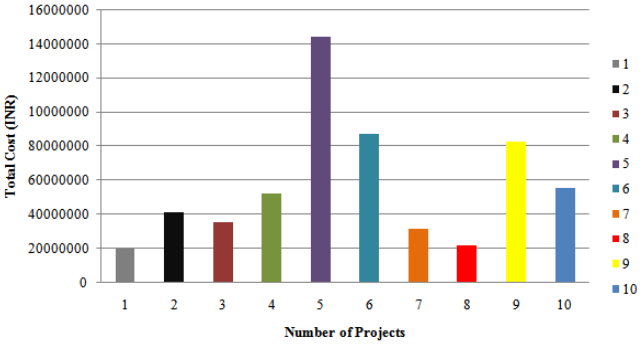


**Fig.8** Total Estimated Cost

Figure 8 represents the total estimated cost for 10 different projects represented by different colors. X-axis and y-axis represents the number of projects and total cost in (INR). The cost is estimated automatically by passing the ground coverage areas as well as the built up area of the project into the input layer of neural network. The processing element process or do calculation and provide the total cost as an output at the output layer. The screenshots obtained after analyzing cost using ANN is shown in figure below.

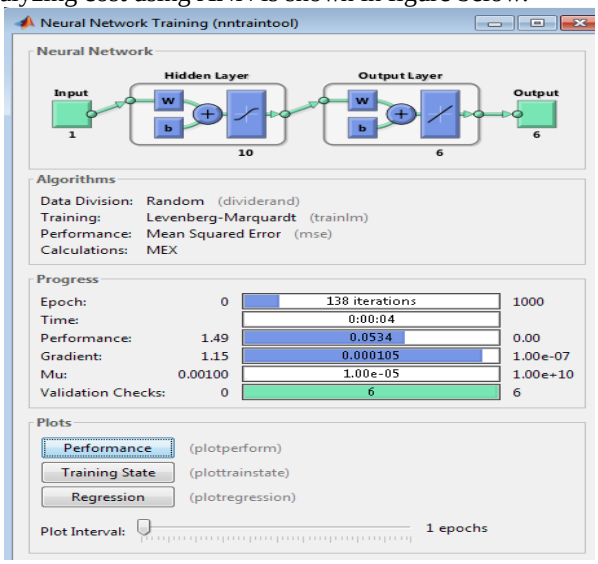


**Fig.9** Training of ANN

Ground Coverage Area, Built Up Area, Utilities (%), Contractor Profit (%), Wastage (%), Contingency (%) and unit cost are the input of ANN in terms of single dimension matrix. The output of ANN obtained on the basis of six different inputs data with 10 hidden neurons. Where hidden neurons are act as a carrier to transfer information for input layer to output layer.

## VI. CONCLUSION

The aim of this research paper is to design a new model for early cost estimation of educational building projects in India. The cost estimation model has been developed in MATLAB simulator that helps the participant involved in construction projects. The following points are concluded after the implementation of the work.

i. The cost estimated using this model is highly accurate due to the utilization of artificial intelligence (AI).
ii. AI also reduces human effort.
iii. Cost estimation is fast and requires less data (i) ground coverage area of the project and (ii) built up area.

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