ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

PRE-DESIGN STAGE CONSTRUCTION COST PREDICTION OF BUILDING PROJECTS USING ARTIFICIAL NEURAL NETWORK

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DOI: 10.5281/zenodo.891900

ABSTRACT
Cost is one of the major factors in decision making at the early stages of a building construction process. The real challenge in cost estimation of building projects at the early stage is lack of information. So decision making is important in cost estimation for building design processes which needs an estimation tool for designers, estimators and project managers. Artificial neural networks (ANN) method is most effective and appropriate technique for initial stage cost estimation. This project is highlighting the study of Application of Artificial neural network (ANN) for pre design cost estimation of building projects to investigate and overcome problems caused in estimating project cost at pre-design stage of building projects. As well as to develop & test a Graphical User Interface (GUI) model of cost estimating for building projects in the early design phase using MATLAB software. Twelve actual real-life cases of building projects constructed in Pune District during the Three year period 2014-2017 were used as training materials. The architecture of Artificial neural network is presented for the estimation of the project cost at the initial stage.

KEYWORDS: Artificial neural network, cost estimation, Graphical User Interface (GUI), MATLAB

I. INTRODUCTION
Cost estimating is a fundamental piece of construction projects, where cost is considered as one of the real criteria in basic leadership at the beginning times of building configuration process. The exactness of estimation is a basic factor in the achievement of any construction extend, where cost invades are a noteworthy issue, particularly with current accentuation on tight spending plans. Without a doubt, cost invades can prompt cancellation of a venture. At times, a potential invade may bring about changing a venture to an outline to-cost assignment.

Along these lines, the cost of construction extend should be evaluated inside a particular exactness run, however the biggest deterrents remaining before a cost gauge, especially in beginning time, are absence of preparatory data and bigger instabilities because of designing arrangements. All things considered, to beat this absence of point by point data, cost estimation strategies are utilized to inexact the cost inside a worthy precision go. Cost models give a compelling other option to conceptual estimation of construction costs. In any case, improvement of cost models can be trying as there are a few elements influencing on extend costs. There are normally different and uproarious information accessible for demonstrating.

II. METHODOLOGY
- Literature review conduction of previous studies that are related to construction cost estimation and using ANN.
- Relevant data Collection corresponding to the important factors identified in the previous step
- Application of ANN technique using MATLAB software for modeling the neural network in the following steps:
    - Importing the collected data set in MATLAB
    - Create ANN - Train ANN - Test ANN - Save ANN
    - Create Graphical User Interface Model.
- Evaluation of the performance of developed ANN GUI model in actual projects.

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- **Literature review conduction of previous studies that are related to construction cost estimate and paying special attention of using ANN:**

At the beginning of this research various papers relevant to cost estimation in construction industry were collected & reviewed, those studies had worked on new approach of cost estimation like ANN models.

- **Relevant data Collection corresponding to the important factors identified in the previous step:**

Collected research papers were used to identify the main parameters which affect building projects cost. For the need of many data in building the neural network models, many historical building projects that were done between 2012 and 2017 in Pune were collected from construction firms.

- **Applying ANN technique using MATLAB software for modeling the neural network in the following steps:**
  - **Importing the collected data set in MATLAB:**

Data sheets of 12 project estimates were collected and imported in MATLAB software. Excel sheets were converted into MATLAB file format put as Input & Output parameters.

  - **Create ANN - Train ANN - Test ANN - Save ANN**

After importing those data sheets ANN is created. That ANN is trained according to data sheets provided. During training ANN was provided with required algorithm and Neural Network Architecture. Number of Input parameters, Number of Output parameters, Learning Algorithm, Neural Network Architecture, Learning method, Number of hidden Layers were also assigned to ANN. After training ANN is tested with some of the given data sheets to check whether ANN is trained properly or not. After testing ANN is saved.

  - **Create Graphical User Interface Model.**

After testing & saving ANN, Graphical User Interface model is created in MATLAB according to required Input & Output parameters. That created GUI model is provided with the saved ANN and checked with data sheets which were already put in the saved ANN.

- **Evaluation of the performance of developed ANN GUI model in actual projects.**

The developed ANN is then evaluated in actual projects with provided Input parameters. After analyzing the data, many models were built and trained with various project data sheets and the best model was selected.

III. DATA COLLECTION

Primary Data:

The process of collecting information that is related to cost estimation problems is a difficult task, because such information is the property of each construction firm. Construction firms usually do not agree to share their cost data with others. Moreover, most firms believe that such information usually makes a difference in being more competitive in the market. However, great effort and time were exposed to collect adequate account of building projects to establish a neural network model. The methodology for collecting these data was based on personal contacts with construction firms in Pune city.

In this study, a detailed analysis of data and results will be presented and elaborated. The data used in this study was collected from 12 project estimates in the past three years. A data sheet was prepared and used to extract all useful information from each project.

Secondary Data:

Literature studies was the process in determining the key parameters. Many research papers have been referred for selecting most influential input and output parameters for developing ANN model. Clearly there is a generous convergence in recognizing factors affecting on cost of building projects in Pune. Therefore, it can be adopted for recognizing the most influential factors.

Influential Factors Adopted in the Research:

Literature studies was the process in determining the key parameters. According to previous techniques, it is obvious that there is a substantial convergence in identifying factors affecting on cost of building projects in

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Pune. Therefore, it can be simply adopted the most influential factors. Table 5.2 shows the most influential factors that were adopted in this study and were used in building the models as input parameters. It contains five factors.

Table 3.1 Influential Factors of building project Cost adopted in this research

No.	Description	Range
1	Number of Buildings	1 to 11 No.s
2	Number of floors per building	4 to 11 No.s
3	Total slab area in Square Feet	9500 to 800,000
4	Total No. of Lifts	0 to 22
5	Total No. of Staircases	1 to 22

IV. DATA ANALYSIS

4.1 Model Development

Introduction

A Neural Network training program, MATLAB version 2016a, was used as a standalone environment for Neural Networks development and training. Moreover, for verifying this work, a plentiful trial and error process was performed to obtain the best model architecture. The following sections present the steps performed to design the artificial neural network model, the limitation of adopted model, and finally the discussion and analysis of results. Step by step presentation of artificial neural network model design, the limitation of ANN model and the discussion & analysis of results.

Model Limitations

In spite of great accuracy of using ANN in cost estimation, it has a considerable defect, as it depends mainly on historical data; this dependency has several disadvantages as the following;

- Diversity of variables for effective factors is limited to what available in collected data.
- Data should contain sufficient projects for each variable.
- New variables which was not included in adopted model will not be handled.

Therefore, in this study most of construction variables used were included except those that haven't enough frequency. After analyzing the collected data, there was found that some limitations on input parameters should be assigned to give the best output. Table 6.1 illustrates the available range of input data in ANN model as; Number of Buildings has a range between 1 - 11 No.s, Number of slabs per building ranges from 8 to 11 slabs, Total slab area in Square Feet has a range between 45000 SqFt - 800,000 SqFt, Number of Lifts also ranges from 2 to 22 and Total No. of Staircases has a range between 2 - 22 for the whole buildings project.

Model Building

There are several types of ANN softwares are used for prediction of the cost requires in future based on the previous data like Neurosolution, MATLAB, SPSS…etc. Many researchers used MATLAB application in building their neural networks that it achieved good performance as (Mohammed Arafa and Mamoun Alqedra 2011).

The developed model in this research based on MATLAB version 2016a. It was selected for its ease of use, speed of training, flexibility of building and executing the NN model. Model developer also has the flexibility to specify his own neural network type, learning method, activation functions, learning rate, number of hidden layers/neurons and graphical presentation & interpretation of the results. Finally, it has multiple criteria for training and testing the model.

I) Data Organization

The first step was to organize the excel spreadsheet in implementation of the ANN model in MATLAB application. Then, specifying the input factors, which consist of 5 factors; Number of Buildings, Number of slabs per building, Total slab area in Square Feet, Total No. of Lifts and Total No. of Staircases. The desired parameters (outputs) which are 18 in no.s are Earth Work, Concrete, Reinforcement Steel, Blockwork/Brickwork, External Plaster, Gypsum/Internal Plaster, Waterproofing Work, Tiling Work, Aluminium Work, Doors-Carpentry Work, Fabrication Work, Plumbing Work, Electrification, Painting Work, Fire Fighting Work, Solar Water System, Lift & Elevator Works and Grand Total.

II) Data Set

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The available data were divided into three sets namely; training set, validation set and test set. Training and Validation sets are used in learning the model through utilizing training set in modifying the network weights to minimize the network error, and monitoring this error by cross validation set during the training process. However, test set does not enter in the training process and it hasn't any effect on the training process, where it is used for measuring the generalization ability of the network, and evaluated network performance (Arafa & Alqedra, 2011).

In the present study, the total available data is 12 estimate sheets that were divided logical randomly, according to previous literatures, into three sets with the following ratio:

- Training set (includes 8 datasheets ≈ 70%).
- Validation set (includes 2 datasheets ≈ 15%).
- Test set (includes 2 datasheets ≈ 15%).

III) Building Network

Once all data were prepared, then the subsequent step is represented in creating the initial network by selecting the network type, number of hidden layer/nodes, transfer function, learning rule, and number of epochs and runs.

An initial neural network was built by selecting the type of network, number of hidden layers/nodes, transfer function, and learning rule. However, before the model becomes ready, a supervised learning control was checked to specify the maximum number of epochs and the termination limits.

4.2 Model Training

The objective of training neural network is to get a network that performs best on unseen data through training many networks on a training set and comparing the errors of the networks on the validation set (Dindar, 2004). Various network parameters such as number of hidden layers, number of hidden nodes, transfer functions, number of epochs, learning rate and learning rules were trained multiple times to produce the best weights for the developed GUI model. As a preliminary step to filter the preferable neural network type, a test process was applied for most of available networks in the application. Two types Multilayer Perceptron (MLP) and General feed Forward (GFF) networks were chosen to be focused in following training process due to their good initial results.

It is worthy to mention that, previous models that have been applied in the field of cost estimation by neural networks used earlier two types of networks because best results were given by them.

4.3 Model Results

As mentioned above, the purpose of testing phase of ANN model is to ensure that the developed model was successfully trained and generalization is adequately achieved. Through a system of trial and error guided by earlier recommendation, the best model that provided more accurate cost estimate without being overly complex was structured of Multilayer Perceptron (MLP) includes one input layer with 5 input neurons and one hidden layer with (15 hidden neurons) and finally one output layer with 18 output neuron. However, the main downside to using the Multilayer Perceptron network structure is that it required the use of more nodes and more training epochs to achieve the desired results. Figure 4.1 summarizes the architecture of the model as number of hidden layer/nodes, type of network and transfer function.

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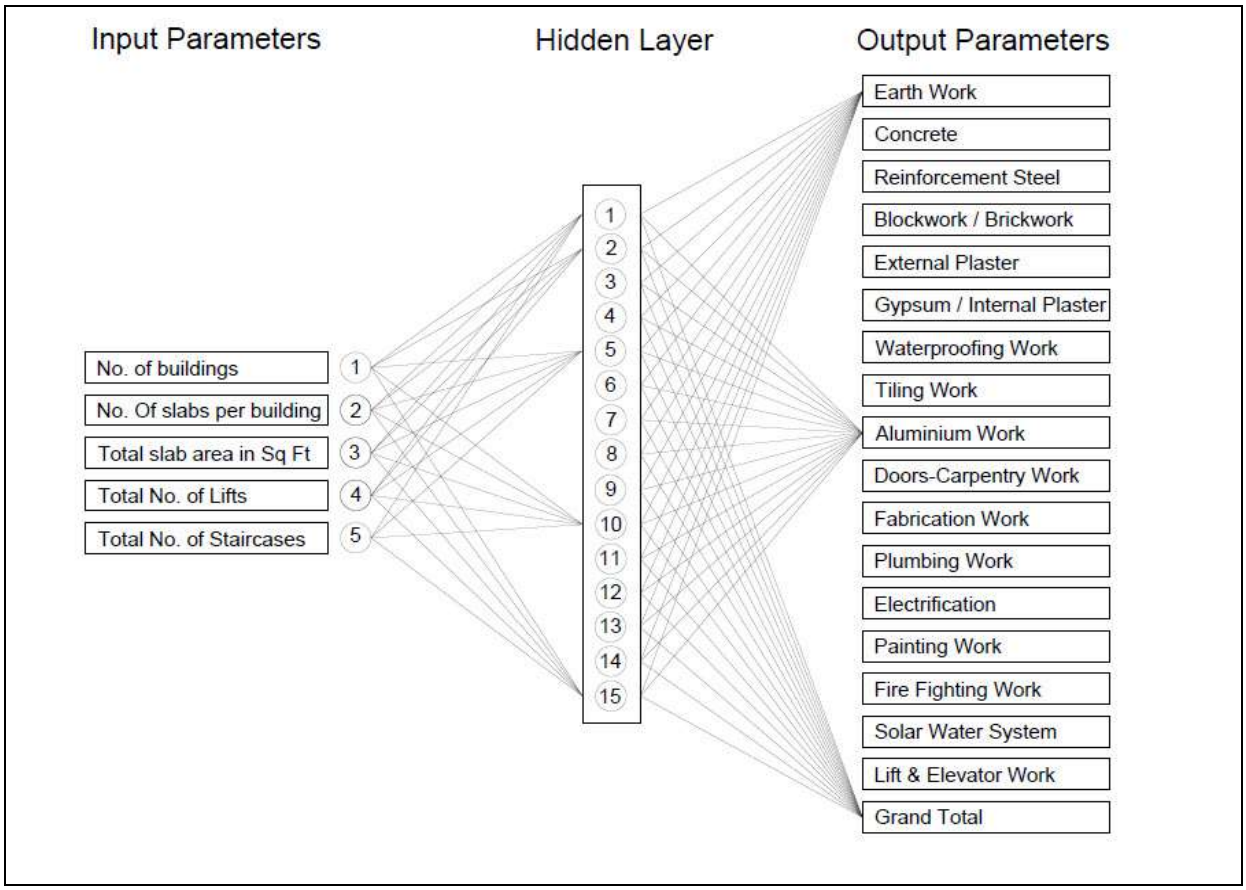

Software Used : MATLAB 2016a version
Algorithm : Backpropagation Multilayer Perceptron Network
Neural Network Architecture : Feedforward network
Learning : Supervised Learning
No. of Input parameters : 5
No. of Output parameters : 8
No. of Hidden layers : 15

4.4 Results Analysis

The testing dataset was used for generalization that is to produce better output for unseen examples. Data from three projects were used for testing purposes.

MATLAB Developed GUI shown in figure 4.2 was used for testing the adopted model accordingly to the weights adopted. Tables 4.1, 4.2 and 4.3 present the results of these three projects with comparing the real cost of tested project with estimated cost from neural network model and an absolute error with both price and percentage are also presented.

Figure 4.1 Architecture of the model

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Figure 4.2 MATLAB Developed (GUI) Graphical User Interface

Table 4.1 Project 1: Input and Output Parameters

Project -1 which was tested for output was given input parameters in the developed model as follows:

Sr. No.	Input Parameters

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1	No. of buildings	1
2	No. of slabs per building	11
3	Total slab area in Square Feet	95423
4	Total No. of Lifts	3
5	Total No. of Staircases	3

Estimated results of Project -1 compared with output parameters given by the developed ANN model. Percentage error between Estimated cost & ANN Model cost Shown in below Table.

Output Parameters				
Sr. No.	**Description**	**Estimated Amount-Athashree**	**ANN Model Amount**	**Percentage error**
1	Earth Work	3 965 013.95	2 806 660.00	29.21%
2	Concrete	38 915 945.34	46 349 400.00	-19.10%
3	Reinforcement Steel	31 922 610.34	23 221 800.00	27.26%
4	Blockwork / Brickwork	10 651 266.65	13 410 800.00	-25.91%
5	External Plaster	9 135 328.93	11 208 100.00	-22.69%
6	Gypsum / Internal Plaster	5 922 972.72	5 906 910.00	0.27%
7	Waterproofing Work	3 311 212.80	3 103 840.00	6.26%
8	Tiling Work	19 688 290.88	15 061 100.00	23.50%
9	Aluminium Work	3 739 823.26	2 752 380.00	26.40%
10	Doors-Carpentry Work	5 657 595.84	7 122 210.00	-25.89%
11	Fabrication Work	3 309 828.66	2 224 440.00	32.79%
12	Plumbing Work	7 860 691.41	9 193 330.00	-16.95%
13	Electrification	2 100 064.06	1 504 640.00	28.35%
14	Painting Work	7 315 694.28	5 609 390.00	23.32%
15	Fire Fighting Work	920 648.60	825 084.00	10.38%
16	Solar Water System	2 201 081.00	1 409 420.00	35.97%
17	Lift & Elevator Work	6 864 000.00	5 628 430.00	18.00%
18	Grand Total	196 668 801.97	232801000.00	-18.37%

Table 4.2 Project 2: Input and Output Parameters

Project - 2 which was tested for output was given input parameters in the developed model as follows:

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Sr. No.	Input Parameters	
1	No. of buildings	1
2	No. of slabs per building	11
3	Total slab area in Square Feet	97711
4	No. of Lifts	2
5	No. of Staircases	2

Estimated results of Project -2 compared with output parameters given by the developed ANN model. Percentage error between Estimated cost & ANN Model cost Shown in below Table.

Output Parameters				
Sr. No.	**Description**	**Estimated Amount - Forest T1**	**ANN Model Amount**	**Percentage error**
1	Earth Work	1 994 164.35	1721880	13.65%
2	Concrete	34 929 317.80	29858300	14.52%
3	Reinforcement Steel	22 637 448.70	17021500	24.81%
4	Blockwork / Brickwork	7 691 765.20	8068910	-4.90%
5	External Plaster	7 479 765.42	9527490	-27.38%
6	Gypsum / Internal Plaster	5 779 229.14	4085280	29.31%
7	Waterproofing Work	2 833 009.55	2927910	-3.35%
8	Tiling Work	17 007 435.67	12580700	26.03%
9	Aluminium Work	3 986 866.02	2826300	29.11%
10	Doors-Carpentry Work	4 606 111.12	4166150	9.55%
11	Fabrication Work	4 182 731.72	2971970	28.95%
12	Plumbing Work	6 189 473.17	8053810	-30.12%
13	Electrification	7 316 920.00	5879030	19.65%
14	Painting Work	6 025 643.40	5494760	8.81%
15	Fire Fighting Work	1 560 000.00	980723	37.13%
16	Solar Water System	2 277 834.66	900817	60.45%
17	Lift & Elevator Work	3 432 000.00	3370560	1.79%
18	Grand Total	177 468 938.05	162812000	8.26%

Table 4.3 Project 3: Input and Output Parameters

Project - 3 which was tested for output was given input parameters in the developed model as follows:

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Sr. No.	Input Parameters	
1	No. of buildings	1
2	No. of slabs per building	11
3	Total slab area in Square Feet	101026
4	No. of Lifts	3
5	No. of Staircases	3

Estimated results of Project -2 compared with output parameters given by the developed ANN model. Percentage error between Estimated cost & ANN Model cost Shown in below Table.

Output Parameters				
Sr. No.	**Description**	**Estimated Amount - Pebbles**	**ANN Model Amount**	**Percentage error**
1	Earth Work	3 004 970.07	2878330	4.21%
2	Concrete	41 186 669.33	49360000	-19.84%
3	Reinforcement Steel	33 128 030.67	24465900	26.15%
4	Blockwork / Brickwork	11 080 882.97	13828500	-24.80%
5	External Plaster	8 993 244.38	11563100	-28.58%
6	Gypsum / Internal Plaster	5 170 419.08	6052970	-17.07%
7	Waterproofing Work	4 531 024.45	3382160	25.36%
8	Tiling Work	20 724 895.31	15545500	24.99%
9	Aluminium Work	4 392 415.89	3031990	30.97%
10	Doors-Carpentry Work	8 452 240.16	7408170	12.35%
11	Fabrication Work	3 750 650.95	2546360	32.11%
12	Plumbing Work	7 696 429.36	9631750	-25.15%
13	Electrification	1 900 064.06	1206680	36.49%
14	Painting Work	6 269 258.34	5883040	6.16%
15	Fire Fighting Work	1 396 636.00	902757	35.36%
16	Solar Water System	2 332 212.00	1492980	35.98%
17	Lift & Elevator Work	6 864 000.00	5653120	17.64%
18	Grand Total	211 401 141.93	243172000	-15.03%

Table 4.4 Mean Percentage Error of testing datasets of all three projects

Sr. No.	Description	Percentage error	

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		Project1	Project2	Project3	Mean Percentage error
1	Earth Work	14%	4%	29%	15.69%
2	Concrete	15%	20%	19%	17.82%
3	Reinforcement Steel	25%	26%	27%	26.07%
4	Blockwork / Brickwork	5%	25%	26%	18.54%
5	External Plaster	27%	29%	23%	26.21%
6	Gypsum / Internal Plaster	29%	17%	0%	15.55%
7	Waterproofing Work	3%	25%	6%	11.66%
8	Tiling Work	26%	25%	24%	24.84%
9	Aluminium Work	29%	31%	26%	28.83%
10	Doors-Carpentry Work	10%	12%	26%	15.93%
11	Fabrication Work	29%	32%	33%	31.28%
12	Plumbing Work	30%	25%	17%	24.07%
13	Electrification	20%	36%	28%	28.17%
14	Painting Work	9%	6%	23%	12.76%
15	Fire Fighting Work	37%	35%	10%	27.63%
16	Solar Water System	60%	36%	36%	44.13%
17	Lift & Elevator Work	2%	18%	18%	12.48%
18	Grand Total	8%	15%	18%	13.89%

Percentage error of all three projects i.e. Project - 1, Project – 2 & Project – 3 compared and Mean Percentage error is calculated as follows:

- **Mean Percentage Error**

The mean percentage error of the model is calculated from the test cases as shown in Table 4.4, which equals 13.89% for Grand Total of the Project and 22.45% for all other activities together, this result can be expressed in another form by accuracy performance (AP) according to Wilmot and Mei, (2005) which is defined as (100−MPE)%.

AP= 100% - 13.89% = 86.11% for Grand Total of the Project

AP= 100% - 22.45% = 77.55% for All Other Activities Together of the Project

It is a good result especially when this estimate in conceptual phase where no details or drawings are available.

V. CONCLUSION

Several steps and procedures were conducted in order to achieve this aim to develop a new model for early cost estimate of building projects by using an ANN as following:

- MATLAB 2016a version was used to develop ANN model. Multilayer Perceptron network model (MLP) which structured from one input layer included 5 input neurons, one hidden layer contained 15 hidden neurons, 18 output neurons on Backpropagation algorithm.
- The accuracy performance of the adopted model for "Grand Total of the Project" recorded 86.11% where average percentage for all other parameters is 77.55% between the output obtained from model and the actual budget value of the project.

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ISSN: 2277-9655
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CITE AN ARTICLE

Bhirud , A. N., & Ambrule, V. R. (2017). PRE-DESIGN STAGE CONSTRUCTION COST PREDICTION OF BUILDING PROJECTS USING ARTIFICIAL NEURAL NETWORK . ***INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY, 6*****(9), 314-325. Retrieved September 15, 2017.**