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Estimating the Final Cost of Construction Project Using Neural Networks: A Case of Yemen Construction Projects

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***Abstract**: Cost is an important aspect to everyone, especially in the construction projects. For any project requires accurate cost diction in order to inspire the decision either forward or cancel the project. Moreover, predicting the cost plays a key role in the successful completion of the construction projects. Due the lack in information, details, drawings and many important factors that affecting in estimation the cost during planning phase, the project will be at risk. Therefore, the cost estimation plays a significant role in construction project decisions and represents the most important corner in iron triangle of construction management. In order to success the construction projects we need technique to estimate the cost with high degree of accuracy and less error. In the present investigation, the model built by applying both quantitative approach and qualitative approach to identify the factors (variables) as inputs of the model. 85 projects are used for developing, training and testing the ANNs model, the output of this model is the expected construction costs of the projects. To validate the model, 14 projects as sample have tested to predict the cost with high degree accuracy and acceptable error. Consumer Price Index, cost of construction materials, type of building, market conditions, structural system, site Area, type of slab, other Supplementary buildings, location of the Project, project Size, type of foundation, building closeness, and fluctuation in the Currency are the main factors affecting in construction buildings costs. These factors have been used as inputs in ANN model and all data is extracted from the historical projects, the model has been developed and trained for 70 projects and compared the actual cost with predicted cost. The model was validated throughout sample of projects. 13- 17- 1 model was the best between 15 models are developed, 6% is the mean absolute percentage error for model is tested. The results are clearly provided a good indicator for predicting the construction buildings costs in the future with high degree of accuracy.*

Keywords: *Cost Factors, Artificial Neural Network System, Feed Forward Network, Multilayer Perceptron, Back Propagation Error, Developing the model.*

I. INTRODUCTION

A project consists of a number of activities. Each of these activities consumes resources. Resources cost money. We can take certain steps through which we can control the costs of these activities. Project cost management is all about controlling cost of the resources needed to complete project activities. Apart from these controllable costs, there are certain aspects over which we do not have any control. These are called uncontrollable costs and they are subject matter of risk management, taken up separately. Figure 1 is illustrated bellow three corners project constraints in construction project management, the cost, time, and quality are callediron triangle of the project. Artificial neural networks try to reproduce the generalization abilities of a human neural system. Neural Networks are particularly effective for complex estimating problems where the relationship between the variables cannot be expressed by a simple mathematical relationship. They are computer programs simulating the biological structure of the human brain which consists of tens of thousands of highly interconnected computing units called neurons. An Artificial Neural Network can be constructed to simulate the action of a human expert in a complicated decision situation. Construction management and cost engineering have made tremendous advances to address overrun and delay, minimizing uncertainties, productivity estimation. A neural network is applied for prediction performance construction projects, estimating LCC cost at each stage of construction projects; training models without need for more detailed design, ANN approach provided good predicting ability despite the non-uniform distribution and incompleteness data [1-3]. A few techniques such as regression, and traditional methods, artificial neural network technique is utilized for predicting costs in various construction projects, which address the problems to enable the estimator of cost predicting accurate cost in construction building projects.

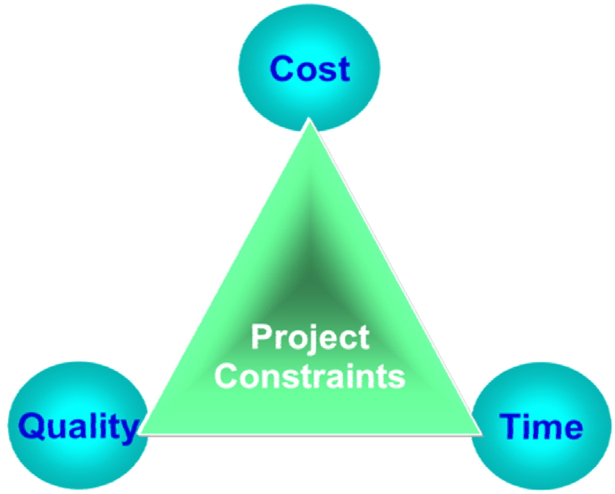

Fig. 1: Iron Triangle in Construction Management

II. LITERATUREREVIEW

Kumar Neeraj JHA2004 (1-6), Cost estimates of different accuracies are required by different agencies for different purposes in different stages of the project! The primary objective of an estimate is to enable one to know beforehand the cost of the work, though the actual cost is only known after the completion of the work from the accounts of the complete work. If the estimate is prepared carefully, there will not be much difference in the estimated cost and actual cost. For accurate estimate, the estimator should be experienced and fully acquainted with the method of construction. The estimate may be prepared approximately in a manner explained earlier or may be made in details, item-wise. In general, a choice of the method estimation to be used depends upon the nature of the project, the life- cycle phase, the purpose for which the estimate is required, the degree of accuracy desired and the estimating effort employed. AL-Zwainy 2012[4], Neuron computing architectures can be built into physical hardware (or neuron computer, or machine) or neuron software languages (or programs) that can think and act intelligently like human beings. Among various architectures and paradigms, the back-propagation network is one of the simplest and most practicable networks being used in performing higher level human tasks such as diagnosis, classification, decision-making, planning, and scheduling. The neural network based modeling process involves five main aspects: (1) data acquisition, analysis and problem representation; (2) architecture determination; (3) learning process determination; (4) training of the network; and (5) testing of the trained network for generalization evaluation, (Wu and Lim 1993).Ajibade Ayodeji Aibinu, et al. 2011(5) Pre-tender estimates are susceptible to inaccuracies (biases) because they are often prepared within a limited timeframe, and with limited information about project scope. Inaccurate estimation of project uncertainties is the underlying cause of project cost overruns in construction. Hashem AL-Tabatbi 1997(7), a neural network model to predict cost performance of construction project is presented, first knowledge representation formalism for cost performance prediction is developed, considering various direct cost elements, and second, the capability of networks, as mapping tools is explored to develop a relation between the construction environmental variables and the project cost performance.

Dr. Zeyad S. et al. 2014(9), A neural network was developed to predict the early stage cost of the buildings. A large number of data was collected from different structure for developing and training lf the ANN model. There are seven key parameters influencing the cost of buildings, the ANN model had one hidden layer with seven neurons, one neuron representing the early cost estimate of the buildings formed the output layer off the ANN model. Roxas, et al. 2014(10), The ANN approach provided good predicting ability despite the non-uniform distribution and incompleteness of the data set. Statistical analysis can be performed like considering the type of the building, weather low rise, mid-rise and high rise. Extensive manipulation of the data to be used the MATLAB program can be explored to improve the results. A. M. El- Kholy 2015 (12), the second model based on case based reasoning. Validation of the two models revealed that regression model has prediction capabilities higher than that of CBR model in predicting cost overrun percentage for construction projects. On the other hand, testing the case based reasoning model's effectiveness with respect to the weight assignment method for attributes revealed that best results are obtained when applying absolute standardized coefficient (β).

III. METHODOLOGY

To develop the parameters cost estimation model by applying the artificial neural networks methodology is the essence of this research, which takes the building projects to predict the final cost of construction building projects. This study adopts upon the historical data to training this methodology, using the main factors affecting as inputs to provide historical data to make estimation cost for new projects. The necessary information and required projects data were collected to build the model of estimation construction cost of building projects.

Conceptual cost estimation, cost control, cost overrun, cost codes and cost management are reviewed to identify the main topics to be handled in this research. All types of artificial neural networks (ANNs), their structure, and applications are outlined. To achieve the objective of the research, development artificial neural networks model for construction projects cost. The research strategy can be classified into two types namely, quantitative approach and qualitative approach. The both types quantitative and qualitative approach are used to collect thee data of the projects and thee information about the factors which influencing in the construction building cost.

This research methodology consists from two stages:

A. *Research Strategy*

1) *Theoretical study :* It is involving review the cost estimation and (ANNs) technique from the references, thesis, journal papers, and books were published in project management field relating to the subject of research
2) *Field work :* It is involving the following steps:
3) Description and selection the factors that influencing the costs of building construction projects.
4) Pilot study involving interviews are used to modify and improve the draft questionnaire
5) Factors are identified and categorized in different groups before sending the final questionnaire to collect the respondents
6) A questionnaire survey methodology is employed to determine and rank these factors according to their levels of influence on the cost of building construction project using SPSS program.
7) Developing of NN model to predict the cost of building construction projects using MATLAB SOFTWARE program.
8) Validation of the NN model.

B. *Historical Data Collection*

Based on thesis methodology and after determining the most important factors, data for training and testing the proposed artificial neural networks model were collected. These data were gathered from real life projects conducted from 2000 to 2017 in Yemen. This process was done using a data collection. (86) Construction buildings projects are collected from Yemen. All data required to construct the model have been collected from ministry of work in Yemen and the companies that executed these projects to compare the estimation value with actual cost.

IV. COST PREDICTION USING NEURAL NETWORKS

This chapter explains the incorporation of the previously identified cost factors into construction buildings. These factors that affecting in construction buildings costs are investigated to be as inputs in ANN model to predict the total cost of construction buildings in Yemen. As mentioned in chapter three, 85 projects are prepared and arranged for developing the ANN model. The data is deduced from 85 projects by Microsoft Excel to import it directly into MATLAP program as inputs and outputs.

First step in this chapter is designing the ANN model regarding on the data was collected and analyzed, thereafter, throughout the artificial neural networks technique is applied to prepare cost prediction model. Finally, three processes have done by MATLAB program namely, training, testing, and validating the best model with lees error and highest accuracy.

A. *Design the ANN model*

Designing ANN models are divided into five basics steps namely, (1) Collecting the data, (2) preprocessing data, (3) architecture the network, (4) training the model, and (5) testing the performance of model.

1) *Data Collection:* Collecting and preparing the data is the first step in designing the model. As it is outlined in previous chapters, the main factors that affecting in construction buildings costs and the historical projects (total cost) in period from 2000 to

2015.

2) *Data Pre-processing :* After data collection, the variables were analyzed using mathematical and software methods such a Microsoft Excel and SPSS23 program, to select the main factors that affecting in construction buildings costs.The data preprocessing procedures are conducted to train the ANNs model more efficiently. These procedures are, (1) solve the problem of missing data from the projects, (2) normalize data, and (3) randomize data. The missing data is replaced by Assuming the value that is the nearest to reality such as, some projects the area of them is missing and not founded, regarding to the insulation layer of building surface in (m^2) is taken as area value.
3) *Architecture the Network:* The neural network was built to consist of three parts, the input layer, hidden layers, and output layer. The weights are linked between these layers, all nodes enclosed by weights from inputs to hidden layer and also from hidden layer to output layer.
4) *Input layer,* the first one, enclosing 13 nodes, each node represents one of the selected cost indicators, as concluded in the previous chapter, each cost indicator will be determined by a value; for quantitative indicators, the exact value will be used, however, for qualitative indicators, a preselected value will be used as an indicator for each case, table 1 illustrates the cost indictors used in the input layer and the correspondent determination value for each cost indicator. Finally, all the data in this layer will be scaled from (-1) to (1).
5) *Hidden Layer(s),* the second ordered layer. In this layer(s), the number on nodes (hidden nodes) ware calculated by considering one guidance that the number of hidden nodes must be not less than half the summation of the number of nodes in the input and output layers (Hosny 2011). According to that guidance, the number of hidden nodes will be calculated according to equation 4.1.

$$\text{Minimum hidden nodes} = \frac{\sum(\text{input nodes}+\text{output nodes})}{2} \quad \text{...} 4.1$$

According to the previous guidance, 10 and above hidden nodes were used in this layer, also an activation function will be used to activate data derived into these hidden nodes. In the trial and error practices, another hidden layer will be added to a new model to be used in a deferent set of trials.

B. Activation Function

MATLAB provides built-in transfer functions which are used in this study; linear (purelin), Hyperbolic Tangent Sigmoid (logsig) and Logistic Sigmoid (tansig).

C. Feed-Forward Networks

Neurons in input layer only act as buffers for distributing the input signals xi (i=1, 2 …n) to neurons in the hidden layer. Each neuron *j* in the hidden layer sums up its input signals xi after weighting them with the strengths of the respective connections (*wji)* from the input layer and computes its output (*yj)* as a function *f* of the sum.

$$y_j = f[\sum_{i=1}^{n} w_{ji} x_i] \quad \text{...} 4.2$$

f can be a simple threshold function or a sigmoidal, hyperbolic tangent or radial basis function.

The output of neurons in the output layer is computed similarly. The back propagation algorithm, a gradient descent algorithm, is the most commonly adopted MLP training algorithm. It gives the change Δwji the weight of a connection between neurons (i) and (j) as follow steps:

Step 1: Initialize weight to small random values.

Step 2: While stopping condition is false, do steps 3-10.

Step 3: For each training pair do steps 4-9.

Feed Forward

Step 4: Each input unit receives the input signal x_i and transmits signals to all units in the layer above (hidden layer).

Step 5: Each hidden unit (z_j, j = 1, …, p) sums its weighted inputs signals

$$z_{inj} = v_{oj} + \sum_{i=1}^{n} x_i v_{ij} \qquad \text{4.3}$$

Applying activation function

$$Zj = f(z_{-inj}) \qquad \text{4.4}$$

And send this signal to all units in the above layer (output layer).

Step 6: Each output unit (y_k, k = 1, …, m) sums its weighted input signals

$$y_{ink} = w_{ok} + \sum_{j=1}^{p} z_j w_{jk} \qquad \text{4.5}$$

and applies its activation function to calculate the output signals.

$$y_k = f(y_{ink}) \qquad \text{4.6}$$

D. Back Propagation of Error

The predictive models based upon ANN utilize back-propagation technique along with different training algorithms and methods available in MATLAB. In our research work these methods have been employed for prediction analysis of software estimation. Back-propagation utilizes techniques of supervised learning and presents a target with computed output in each of iteration for the tuning of the network, so that we keep moving toward the point of minimum error.

E. Back Propagation of Error Steps

Step 7:Each output unit (y_k, k = 1, …, m) receives a target pattern corresponding to an input pattern, error information term is calculated as

$$\delta_k = (t_k - y_k) f(y_{ink}) \qquad \text{4.7}$$

Step 8: Each hidden unit (z_j, j = 1, …, p) sums its delta inputs from units in the layer above

$$\delta_{inj} = \sum_{k=1}^{m} \delta_j w_{jk} \qquad \text{4.8}$$

The error information term is calculated as

$$\delta_k = \delta_{inj} f(z_{inj}) \qquad \text{4.9}$$

Step 9: Each output unit (Y_k, k = 1, …, m) updates its bias and weight (j =0, …, p) the weight correction term is given by

$$\Delta w_{jk} = \alpha \delta_k z_j \qquad \text{4.10}$$

And the bias correction in term is given by

$$\Delta w_{ok} = \alpha \delta_k \qquad \text{4.11}$$

Therefore,

$$w_{jk(new)} = w_{jk(old)} + \Delta w_{jk} \qquad \text{4.12}$$

$$w_{ok(new)} = w_{ok(old)} + \Delta w_{ok} \qquad \text{4.13}$$

Each hidden unit (z_j, j = 1, …, p) updates its bias and weights (i=0, …. n), the weight correction term

$$\Delta v_{ij} = \alpha \delta_j x_i \qquad \text{4.14}$$

The bias correction term

$$\Delta v_{oj} = \alpha\delta_j \qquad \text{4.15}$$

Therefore,

$$v_{ij(new)} = v_{ij(old)} + \Delta v_{ij} \qquad \text{4.16}$$

$$v_{oj(new)} = v_{oj(old)} + \Delta v_{oj} \qquad \text{4.17}$$

Where the various parameters used in the training algorithm are as follows.

X: input training data.

x= (x_1 …. xn).

t= (t_1………t_n).

$^{\delta}{}_k$ = error at output unit y_k

$^{\delta}{}_j$ = error at hidden unit z_j

α= learning rate.

V_{oj}= bias on hidden unit j.

F. Testing the Model

In order to evaluate the performance of the developed ANN models quantitatively and verify whether there is any underlying trend in performance of ANN models, statistical analysis involving the coefficient of determination (R2), the root mean square error (RMSE), and the mean bias error (MBE) were conducted. RMSE provides information on the short term performance which is a measure of the variation of predicated values around the measured data. The lower the RMSE, the more accurate is the estimation. MBE is an indication of the average deviation of the predicted values from the corresponding measured data and can provide information on long term performance of the models; the lower MBE the better is the long term model prediction. A positive MBE value indicates the amount of overestimation in the predicated construction buildings costs. The expressions for the aforementioned statistical parameters are:

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(I_{predicted} - I_{actual}) \qquad \text{4.17}$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(I_{predicted} - I_{actual})^2} \qquad \text{4.18}$$

Where Ip, i denotes the predicted construction buildings costs in (R.Y.). Ii denotes the measured construction buildings costs in (R.Y.), and n denotes the number of observations.

IV. RESULTS AND DISUCSSION

A. Programming The Nn Model

MATLAB (2015a) is used to write script files for developing ANN models and performance functions for calculating the error statistics as R^2, RMSE and MSE. It allows the designer to prepare easy matrix manipulation, plotting of functions and data, implementation of algorithms and also provides comprehensive support and enables the user to design and manage the neural networks in a very simple way.

The MLP program starts by reading data from excel file (training data and testing data). "xlsread" function is used to read the data from excel sheets.

Data Input = xlsread ('training data.xlsx');

Data Target= xlsread ('target data.xlsx');

Data Test = xlsread ('testing data.xlsx');

Training data samples are 70 projects prepared to train the model (training samples).

MATLAB helps devise the MLP model by using a feed –forward back propagation network, number of hidden layers, the neurons in each layer, transfer function in each layer, the training function, the weight/ bias, learning function and the performance function have been done throughout designing the NN networks.

My network = newff(input, target, i, tf);Where

tf denotes to transfer function.

i denotes to the number of neurons in hidden layer.

MyNetwork. trainFcn = Rb;

MyNetwork.trainparam.min_grad = 0.00000001;

MyNetwork.trainParam.epochs = 1000;

MyNetwork.trainParam.lr = 0.01;

MyNetwork.trainParam.max_fail =1000;

Where

“trainFcn”: defines the function used to train the network. It can be set to the name of any training function (LRb 'trainRb%Bayesan Regularization back-propagation).

“trainparam.min_grad”: denotes the minimum performance gradient.

“trainParam.epochs”: denotes the maximum number of epochs to train.

“trainParam.lr”: denotes the learning rate.

“trainParam.max_fail”: denotes the maximum validation failures.The MLP network is trained using “trainFcn” train function.

MyNetwork = train(MyNetwork,input,target);The MLP network is tested using “simFcn” testing function.

MyNetwork = train(MyNetwork, test);

B. Developing ANN Model Using MATLAB

MATLAB (2015a) is used to write script files for developing ANN models and performance functions for calculating the error statistics as R^2, RMSE and MSE. It allows the designer to prepare easy matrix manipulation, plotting of functions and data, implementation of algorithms and also provides comprehensive support and enables the user to design and manage the neural networks in a very simple way. Table 1 is shown the input layer and the determination value for each cost indicator (inputs data).

When the training is complete, the network performance should be checked. Therefore, unseen data (testing) will be exposed to the network. Figure.2 and Figure.3 show, respectively, screen captions of the MLP training windows obtained using the “nntraintool” GUI toolbox in MATLAB.

Table 1**:** The Input Layer and the Determination Value for Each Cost Indicator

No.	Code	Cost Indicator	Determination Value
1	I_1	Consumer Price Index	Exact Value
2	I_2	Cost of Construction Materials	Exact Value
3	I_3	Type of building	1- Administrative 2-Commericial 3- Residential 4- Educational

4	I_4	Market Conditions	1- International Market 2- Regional Market
5	I_5	Structural System	1- Concrete 2- Steel 3- Mix
6	I_6	Site Area	Exact Value
7	I_7	Type of Slab	1-Solid Slab 2- Hollow Block 3- Flat Slab
8	I_8	Other Supplementary Buildings	Exact Value
9	I_9	Location of the Project	1- Inside Sana'a 2- Outside (Mountain Area) 3- Outside (Coastal Area) 4- Outside (Desert Area)
10	I_{10}	Project Size	1- Huge 2- Medium 3- Small
11	I_{11}	Type of Foundation	1- Isolated Foundation 2- Combined Foundation 3- Strip Foundation 4- Raft 5-Pile
12	I_{12}	Building Closeness	1- Attached 2- Semi- Attached 3- Separated
13	I_{13}	Fluctuation in the Currency	Exact Value

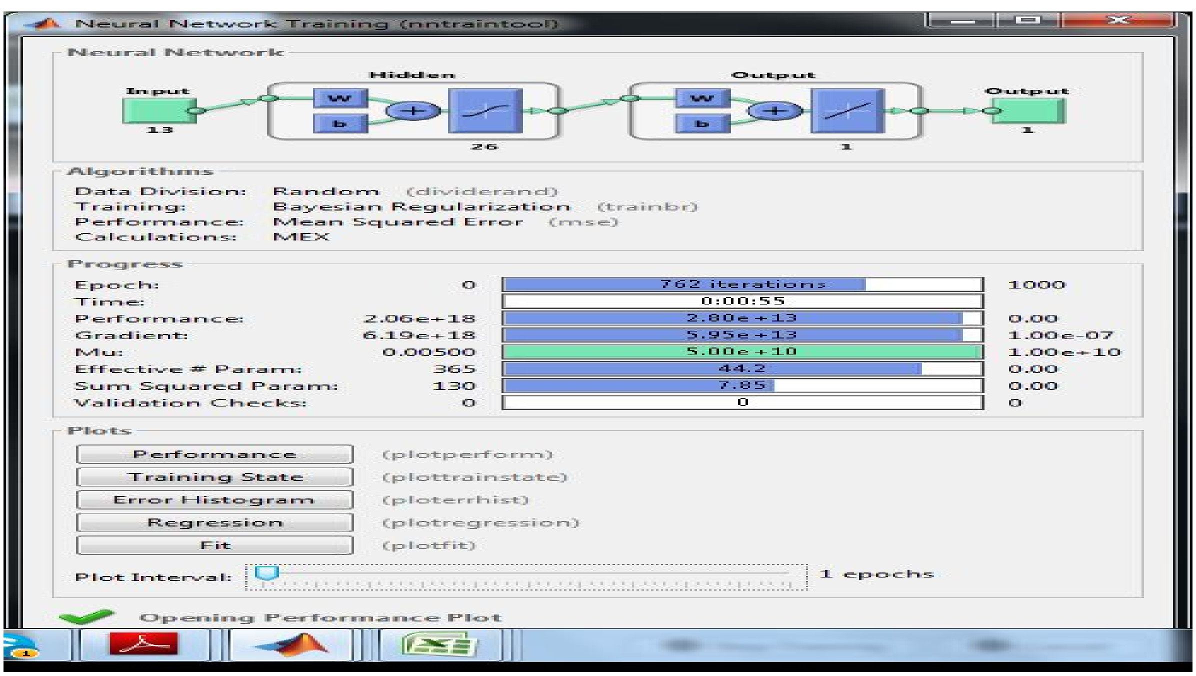

Fig.2:MLP network Training Window

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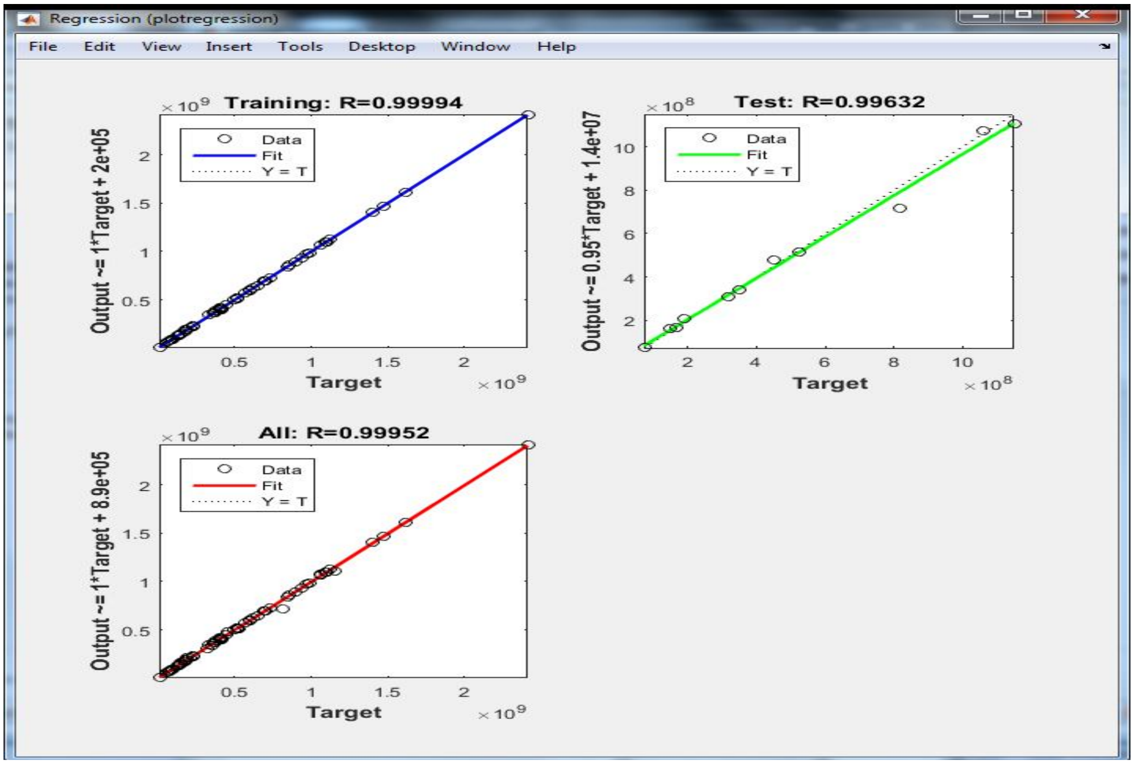

Fig.3: Plot Regression Windows

V. RESULTS AND DISSECTION

This section presents the best achieved results for MLP models. In table 2 is shown the computed values of R^2, MSE, and RMSE for (15) developed ANN models. The network structure is involved three layers and denoted by three numbers, first number indicates the number of neurons in the input layer, second number indicates of the number of neurons in the hidden layer, and third number refers of the neuron in the output layer. (70) Samples are used for training each model, (14) samples are tested of each model. (15) Models are developed.

Table 2: Statistical error parameters of developed MLP models for different network structures

Model	Network Structure	R^2	MSE	RMSE	Error (MAPE)
1	13-10-1	0.966	123805084	1783457158	13.70%
2	13-26-1	0.992	-138465	80722956	9.60%
3	13-13-1	0.997	-1849845	141673859	9.00%
4	13-14-1	0.985	10040353	246248599	11.10%
5	13-15-1	0.873	19242985	466500558	7.90%
6	13-16-1	0.983	4910198	220396357	6.90%
7	13-17-1	0.999	8731530	301556771	6.33%
8	13-18-1	0.992	-3044529	180977326	8.50%
9	13-19-1	0.947	2129605	383907356	9.30%
10	13-20-1	0.996	-6570437	117292898	16.56%
11	13-21-1	0.988	-6748149	213437822	9.40%
12	13-22-1	0.793	-18996349	376171544	11.50%
13	13-23-1	0.961	-1788270	235681033	9.30%
14	13-24-1	0.995	6608044	146971992	9.30%
15	13-25-1	0.979	143769	2408141631	10.13%

#Model (7)13-17-1

Table 3: Statistical error parameters of model 13-17-1

ID	Actual cost	Predicted cost	MSE	RMSE	Error	Evaluation
1	86627200	100126137.2	13498937.24	1613431.598	15.58%	Fail
2	448550650	460019970.8	11469320.84	1370846.04	2.56%	Pass
3	369728000	366658187.2	3069812.754	366912.8029	-0.83%	Pass
4	119969150	125226796.1	5257646.07	628408.9001	4.38%	Pass
5	173184550	166335860.8	6848689.179	818574.9243	-3.95%	Pass
6	535507660	535493726.5	13933.50189	1665.372009	0.00%	Pass
7	500161150	521649939.5	21488789.47	2568401.595	4.30%	Pass
8	149318800	159494543.6	10175743.6	1216233.987	6.81%	Pass
9	1052927604	1101406015	48478411.45	5794278.43	4.60%	Pass
10	626723500	706483436.9	79759936.88	9533135.844	12.73%	Fail
11	1031317200	901663856	-129653344	15496538.61	-12.57%	Fail
12	347323500	330780515.1	16542984.93	1977264.887	-4.76%	Pass
13	69283330	75410712.86	6127382.86	732362.3295	8.84%	Pass
14	127834272	136442035.4	8607763.365	1028824.504	6.73%	Pass

A. Results and Discussion

From 15 models, one model is selected (model 7) to be the best model among all models is investigated.

Network structure of model 10 is 13-17-1 and the statistical parameters are the lowest.

Seventh model, sixth model, fifth model, and eighth model have the better accuracy for predicting the construction buildings costs.

The coefficient of determination R2 is 0.998, 0.997, 0.996 and 0.992 for the models 11, 13, 10 and 8 respectively.

Model 7 has the lowest error is 6.33% and the model 10 has the highest error is 16.56%.

Table 3 is shown the results of the model 13-17-1 using ANN technique. The validation was done through 14 projects are tested, 11 projects passed and the error is accepted and 3 projects failed due missing data. MAPE of this model is calculated as 6% and this value is accepted by low of government (The value to be accepted must be + or – 10% in bidding award). 17 neurons are used in the hidden layer in this model to predict the construction buildings costs; therefore, %Error for these projects in the 13-17-1 model is accurate and reliable enough to be used as a predicting tool at conceptual stage

VI. CONCLUSION

In this study investigation, two stages were carried out to achieve the objectives. Data collection and analysis, and developing ANN model have been done. This study is deduced in few points as following:

Fifteen (15) NNs models were built to predict the cost of the project by using neural network Tool Box software by MATLAB program Through five attributes were taken as predictor variables namely; collect data, preprocessing data, architecture the network, training the model, and testing the model using excel sheet and MATLAP. RMSE, MSE, MAPE, and R^2 were calculated and compared for all 15 models to show the best model. It is observed the error from Bayesan Regularization- back propagation shown the best convergence towards minimum error compared to other algorithms. Among those models is 13- 17- 1 model as its percentage of error is 6% which is the least mean absolute percentage error and its coefficient of determination is 0.9998 for models that have already been tested.

The findings clearly provide a good indicator for predicting the construction costs in the future with high degree of accuracy by using artificial neural network method.

A. Recommendations for Further Study

This subject opens the door for a lot of future researches. The following potential areas of studies, if explored, would provide increased validity to the findings of this thesis: For cost estimation, it is suggested to study all factors separately or as groups and develop the best model, the data collected are not sufficient to cover all government buildings, thus we have to collect more than and add them to the model to improve the error and the missing data must be collected. The model should be augmented to take into consideration the other different types of construction projects. For example: the medical, commercial and other administrative construction projects. The model should be applied to predict the duration, productivity, risk analysis, and claims in construction projects.

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