

A Review on Cost Prediction Analysis of Construction Project Using ANN Model

G.C.Sarode, Shubham E.Chandgude

Professor, Department of Civil Engineering, Dr. D.Y.Patil Institute of Technology Pimpri, Pune, India

M. E Student (Construction and Management), Department of Civil Engineering, Dr. D.Y.Patil Institute of Technology Pimpri, Pune, India

ABSTRACT: Cost estimation is an experience-based task, which involves evaluations of unknown circumstances and complex relationships of cost-influencing factors. An artificial neural network (ANN) is an analogy-based process, which best suits the cost forecasting domain. The primary advantages of ANNs include their ability to learn by examples (past projects), and to generalize solutions for forthcoming applications (future projects). Cost is an important aspect to everyone, especially in the construction projects. For any project requires accurate cost prediction 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. This project is implemented on actual site case study located at Ambegaon Pune under the management of SP Construction Pune (Ganesh Construction). 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

Neural computation is one of the inductive machines learning methodologies, it is most often used to learn, generalize and represent general knowledge. It extracts information from existing data by inductive learning. It is a fundamentally different approach to other information processing approaches. Algorithmic computing is used in cases where the processing can be described as a known procedure or a set of known rules. Neural computation allows the development of information processing for which the rules and relationships knowledge are not available (Hecht-Nielson 1990). Expert systems require rules or instructions, which are executed one at a time to arrive at an answer. By contrast, artificial neural networks take in a great amount of information at once, and then draw a conclusion. Once taught, an ANN looks at new input data and produces an answer instantaneously. A back-propagation neural network consists of a number of layers; each layer synthesized of different number of neurons (processing elements) as depicted in Figure the input layer represents influencing factors of a specific problem. The output layer in which the solution of the problem takes place, e.g. prediction, classification, etc. The hidden layer through which the information is processed. The numbers of hidden layers and hidden neurons are usually determined by trial and error according to the complexity of the problem. Warren mcculloch and Walter Pitts (1943) opened the subject by creating a computational model for neural networks.^[4] In the late 1940s, D. O. Hebb created a learning hypothesis based on the mechanism of neural plasticity that became known as Hebbian learning. Farley and Wesley A. Clark (1954) first used computational

machines, then called "calculators", to simulate a Hebbian network. Rosenblatt (1958) created the perceptron.^[8] The first functional networks with many layers were published by Ivakhnenko and Lapa in 1965, as the Group Method of Data Handling. The basics of continuous back propagation were derived in the context of control theory by Kelley in 1960 and by Bryson in 1961, using principles of dynamic programming.

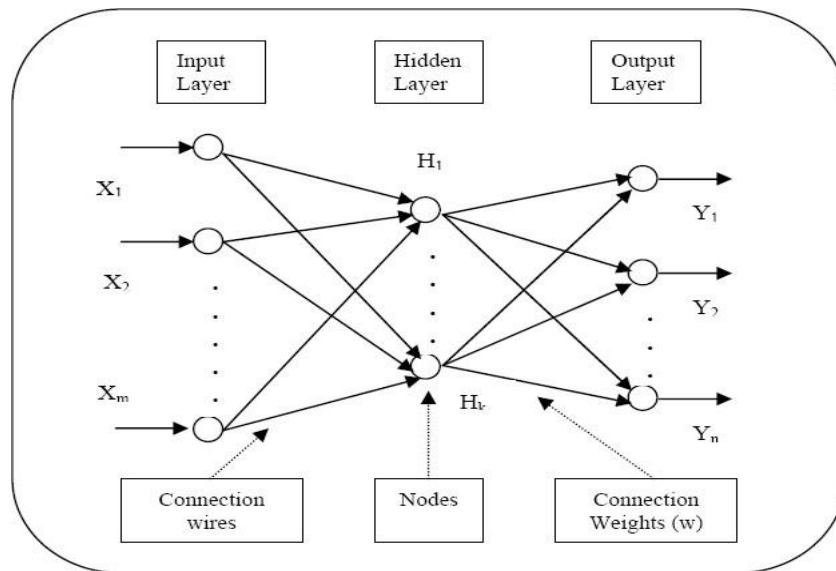


Figure 1. A Simple Artificial Neural Network Structure.

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 below three corners project constraints in construction project management, the cost, time, and quality are called iron 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.

1.1 Artificial Neural Networks used globally

Artificial Neural Networks are the computational models that are inspired by the human brain worldwide. Many of the recent advancements have been made in the field of Artificial Intelligence, including Voice Recognition, Image Recognition, Robotics using Artificial Neural Networks worldwide. Artificial Neural Networks are the biologically inspired simulations performed on the computer to perform certain specific tasks like –

1. Clustering
2. Classification
3. Pattern Recognition

Artificial Neural Networks, in general – is a biologically inspired network of artificial neurons configured to perform specific tasks. These biological methods of computing are considered to be the next major advancement in the Computing Industry. 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 no 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.

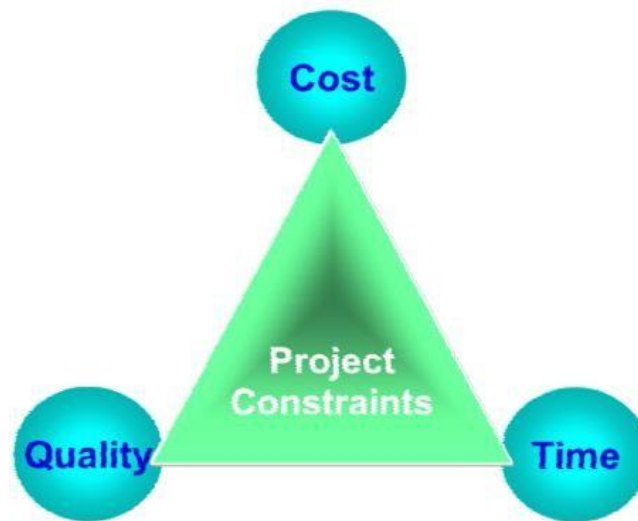


Fig. 2. Iron Triangle in Construction Management

Project owners and construction project managers need a way to focus and prioritize their efforts to control project costs, when their efforts can have maximum impact on the total cost of the project. In the earliest phase of planning and design, only the most basic and functional decisions about the project have been made and the data available for predicting project costs is ambiguous and highly subject to change. Under these conditions, traditional methods for predicting the cost such as built-up, unit cost and expert system estimating become inaccurate or impossible to implement. Stakeholders responsible for controlling project costs are in need for an alternative technique to the traditional cost-based prediction methods to help them predict the cost of their projects using the limited available data in the early phase of the project. The limitations identified with the conventional models stimulated the researchers not to rest on their oars, the drive to evolve better method then became the order of the day. The existing models then were not challenged since they lack applicability until advocators stressed the need to depart from existing research status and go for research output that can be backed with solid theory. He doubts the reliability of existing forecasting models and urged the development of good forecasting method with solid framework for applicability. Artificial neural networks are nonlinear information (Signal) processing devices, which are built from interconnected elementary processing devices called neurons. An Artificial Neural Network (ANN) is an information-processing paradigm that is inspired by the way biological nervous systems, such as the brain, process information. The key element of this paradigm is the novel structure of the information processing system. It is composed of a large number of highly interconnected processing elements (neurons) working in unison to solve specific problems. ANNs, like people, learn by example. An ANN is configured for a specific application, such as pattern recognition or data classification, through a learning process. Learning in biological systems involves adjustments to the synaptic connections that exist between the neurons. This is true of ANNs as well. An artificial neuron is characterized by Architecture (connection between neurons), Training or learning (determining weights on the connections) and Activation function. Artificial Neural Networks have been developed at the recent decades. Artificial Neural Networks are particularly effective for solving complex problems, such as cost estimating problems, where the relationship between the variables cannot be expressed by a simple mathematical relationship. The most important characteristics of Neural Networks is their ability to learn from a set of examples to detect by themselves the relationships that link inputs to outputs, this attribute expresses the capability of Artificial Neural Network not only to manipulate the historical data as human brain, but also to solve complicated problems by searching for the optimal or near optimal solution by using one of the evolutionary learning algorithms.

Neural networks, unlike linear regression, are able to model interdependencies between input data which will inevitably occur when considering construction cost significant variables. For example, the model variables - such as number of storey, gross floor area and number of lifts - will almost certainly be correlated. The awareness of working with accurate cost has thus created a trend among various clients including private, corporate, as well as public clients (government), that prudence in resources allocation is a great necessity for successful execution of project works. However the neural network improves on existing modeling techniques by its use of existing project data is explained, and its role in early stage cost estimation in the 21st century outlined. In order to build such model, the cost factors affecting projects' construction cost that must be firstly investigated. Besides, genetic algorithms based software will

be used to search for near-optimal solution of the network. Various types of algorithms are associated with ANN i.e. Back propagation algorithm, Levenberg-Marquardt algorithm, Gradient descent. The most significantly used is LM which is known as damped least-square method and has been designed specifically with loss function which takes the form of the sum squared error. Next section discusses in brief literature reviewed related to case studies and various tools used.

The primary function of cost estimation is to produce an accurate and reliable cost forecast of a construction project. However, which cost should be forecasted depends on the requirements of a client and also upon the information and data available to develop the model. For instance, a client or a contractor may need to know the lowest tender price at one stage and/or the final project cost at completion stage.

1.2. Problem Statement

In conventional approach Cost is an important aspect to everyone, especially in the construction projects. For any project requires accurate cost prediction 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.

1.3 Objectives of the Project

1. To study and identify the factors affecting on the prediction of cost of building.
2. To use a new technique to estimate the cost with high degree of accuracy and less error.
3. To develop and train the ANN model using MATLAB software to build by applying both quantitative approach and qualitative approach to identify the factors (variables) as inputs of the model.
4. To analysis the factors affecting cost of a construction project.

1.4 Scope of the project

The scope of this project is to develop a new technique to estimate the cost with high degree of accuracy and less error and to develop and train the model using Matlab to build by applying both quantitative approach and qualitative approach to identify the factors (variables) as inputs of the model. This project is implemented on actual site case study located at Ambegaon Pune under the management of SP Construction Pune (GaneshConstruction)

II. REVIEW OF LITERATURE

T.M.S. Elhag, September 1998: Circumstances and complex relationships of cost- influencing factors. An artificial neural network (ANN) is an analogy-based process, which best suits the cost forecasting domain. The primary advantages of ANNs include their ability to learn by examples (past projects), and to generalize solutions for forthcoming applications (future projects). ANNs do not require a prerequisite establishment of rules and reasoning which govern relationships between a desired output and its significant effective variables. Two ANN models have been developed to predict the lowest tender price of primary and secondary school buildings. Thirty projects were involved in this study and their pertaining data was extracted from the BCIS database. Model I utilizes 13 cost-determinant attributes, but in contrast only 4 input variables are involved in developing model II. The findings show that, the two ANN models effectively learned during training stage, and gained good generalization capabilities in testing session. The ANN model I and II managed to achieve average accuracy percentages of 79.3% and 82.2% respectively. PP(225,226)

Van Truong Luu, July 2014. Accurate construction cost estimation in the initial stage of building project plays a key role for project success and for mitigation of disputes. Total construction cost(TCC) estimation of apartment projects in Vietnam has become more important because those projects increasingly rise in quantity with the urbanization and population growth. This paper presents the application of artificial neural networks(ANNs) in estimating TCC of apartment projects. Ninety-one questionnaires were collected to identify input variables. Fourteen data sets of completed apartment projects were obtained and processed for training and generalizing the neural network

(NN). MATLAB software was used to train the NN. A program was constructed using Visual C++ in order to apply the neural network to realistic projects. The results suggest that this model is reasonable in predicting TCCs for apartment projects and reinforce the reliability of using neural networks to cost models. Although the proposed model is not validated in a rigorous way, the ANN-based model may be useful for both practitioners and researchers. It facilitates systematic predictions in early phases of construction projects. Practitioners are more proactive in estimating construction costs and making consistent decisions in initial phases of apartment projects. Researchers should benefit from exploring insights into its implementation in the real world. The findings are useful not only to researchers and practitioners in the Vietnam Construction Industry (VCI) but also to participants in other developing countries in South East Asia. Since Korea has emerged as the first largest foreign investor in Vietnam, the results of this study may be also useful to participants in Korea. PP(144)

Baba Shehu Waziri, March 2017: Artificial Neural Networks has gained considerable application in construction engineering and management in recent time. Over 100 resources published in refereed journals and conference proceedings were screened and reviewed with the view to exploring the trend and new directions of the applications of different ANN algorithms. The study revealed successful applications of ANNs in cost prediction, optimization and scheduling, risk assessment, claims and dispute resolution outcomes and decision making. It was observed that ANN have been applied to problems that are difficult to solve with traditional mathematical and statistical methods. The integration of ANN with other soft computing methods like Genetic Algorithm, Fuzzy Logic, Ant Colony Optimization, Artificial Bee Colony and Particle Swarm Optimization were also explored which generally indicated better results when compared with conventional ANNs. The study provides comprehensive repute of ANN in construction engineering and management for application in different areas for improved accuracy and reliable predictions. PP(50)

Chinchu Mary Jose, April 2017: Quality is the fitness for use, conformance to requirements, predictable degree of uniformity and dependability, at low cost and suited to market. Cost of quality is an essential element of the total cost of any construction project. The main objective of this paper is to develop a neural network model that will enable the construction firms to access cost of quality for any future building project. The different sequences of the model development will be investigated. Moreover, the validity of the proposed model will be evaluated using case study applications. The main 29 factors affecting the expected cost of quality were identified. A questionnaire survey was carried out which was conducted among 60 experts in the construction domain to determine the importance of these twenty nine factors. By using Microsoft Excel, relative importance index of the factors are obtained and the factors with important index more than 70% was selected for a second stage questionnaire survey. Second stage questionnaire survey was conducted among construction experts from different construction industries and the result obtained was used as the input parameters of the proposed cost of quality model. PP(54)

Atheer Mahmood Al-saadi, Oct-Nov 2017: The aim of this study to predict the duration of road projects in republic of Iraq. Historical data was adopted for (99) projects for interval between 2000 to 2017 from Roads and Bridges Directorate (RBD). Artificial Neural Network (ANN) model used to estimate the duration using six variables (length of road, No. of lane, No. of intersection, volume of earth, type of pavement and furniture level). The methodology used in this study included two important parts, the first part, reviewing the literature of the subject (estimating the duration of the road projects), and the second part, used of a program neuroma v.4 to build the models of neural networks to estimate the duration of road project. The results showed strong correlation between actual duration and predict duration by (90.6%), minimizes testing error (3.2%) and training error (4.9%). The MAPE and Average Accuracy Percentage generated by ANN model were found to be (25.73 %) and (74.27%) respectively. Therefore, it can be concluded that ANNs model show very good agreement with the actual measurements. PP(3458)

Smita K. Magdum, Oct 2017: Construction cost prediction is important for construction firms to compete and grow in the industry. Accurate construction cost prediction in the early stage of project is important for project feasibility studies and successful completion. There are many factors that affect the cost prediction. This paper presents construction cost prediction as multiple regression model with cost of six materials as independent variables. The objective of this paper is to develop neural networks and multilayer perceptron based model for construction cost prediction. Different models of NN and MLP are developed with varying hidden layer size and hidden nodes. Four artificial neural network models and twelve multilayer perceptron models are compared. MLP and NN give better results than statistical regression method. As compared to NN, MLP works better on training dataset but fails on testing dataset. Five activation functions are tested to identify suitable function for the problem. 'elu' transfer function gives better results than other transfer function. PP(1549)

Bipin Pal ,February 2018:Cost estimating is one of the most important and challenging activities during project planning, which occurs at the early stages of a project life where limited information is available and many unknown factors affecting the project costs. ANN is a new advent that is used in cost estimation, which is able to lucubrate from experience and examples and deal with non-linear problems. It can perform tasks involving deficient data sets, fuzzy or insufficient information and for highly complex problems. The objective of this study is to review cost estimation models which used Artificial Neural Network (ANN) tool and to suggest the most effectual algorithm for cost prediction and the factors predominantly affecting the total construction costs of building projects. To build CEM, the most effective factors affecting cost in construction projects were identified based on a comprehensive survey among a collected sample of construction relevant model studies. The developed neural network model examines the data set into distinct cases classified on the basis of hidden layers. Each of them containing the independent input neurons, hidden layers and a dependent output neuron. The results of the trained models indicated that neural network reasonably succeeded in estimating the Total construction cost of building projects at the planning stage itself. The average error of test dataset for the adapted model was largely acceptable and can perform as a good indicator regarding the ability of the proposed model to predict the total construction cost of any future construction project at an appreciated degree of accuracy. This paper gives a clear review of implementing the ANN tool in prediction of total cost of building construction projects and the relevant factors affectingit.PP(26)

Mistry. Jignesh. Mukeshchandra,Geetha. K. Jayarajet,sep-oct 2018:Construction projects globally are considered to be multifaceted in nature. This complex work involves estimates of labor production rates during the planning as well as in the execution phase ofthe project.These estimates are habitually carried out by experienced personnel based on his/her experience, may sometimes not have the means to discern the controlling factor factors affecting the production rates. There are various trends in the soft computing techniques for identification of labor production rate in construction, and one being associated with Artificial Neural Networks (ANN). The current study emphasises on critical literature review on factors likely to affect the productivity rates for concreting activities like reinforcement installation, formwork installation and concreting placement and also some of the other industrial activities.PP(50)

Mohammad KabirYaqubi ,May 2019: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 smalltime.PP(845)

Michal Juszczuk, September2019 Construction site overhead costs are key components of cost estimation in construction projects. The estimates are expected to be accurate, but there is a growing demand to shorten the time necessary to deliver cost estimates. The balancing (symmetry) between time of calculation and satisfaction of reliable estimation was the reason for developing a new model for cost estimation in construction. This paper reports some results from the authors' broad research on the modelling processes in engineering related to estimation of construction costs using artificial intelligence tools. The aim of this work was to develop a model capable of predicting a construction site cost index that would benefit from combining several artificial neural networks into an ensemble. Combining selected neural networks and forming the ensemble-based models compromised their strengths and weaknesses.

III. RESEARCH METHODOLOGY



Fig 3. Research 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 buildingcost.

This research methodology consists from two stages:

3.1 Research Strategy

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

Field work: It is involving the followingsteps:

1. Description and selection the factors that influencing the costs of building construction projects.
2. Pilot study involving interviews are used to modify and improve the draft questionnaire 3.3.5) Factors are identified and categorized in different groups before sending the final questionnaire to collect therespondents

3. 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.
4. Developing of NN model to predict the cost of building construction projects using MATLAB SOFTWARE program.
5. Validation of the NN model

3.2 Historical Data Collection

Based on this 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.

3.3 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 MATLAB 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 less error and highest accuracy.

3.4 Design the ANN model

Designing ANN models are divided into five basic steps namely, collecting the data, preprocessing data, architecture the network, training the model, and 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 2) Data Pre-processing : After data collection, the variables were analyzed using mathematical and software methods such as 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,

2) 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 (m²) 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 indicators 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) were 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). Accurate estimation of quantities and costs is a crucial factor in success of construction projects. The main complexity in the cost prediction is dependency on several factors. From those factors one of the most important factors is materials cost. The material cost is main impact factor in construction project for cost estimation which is varying every year. Cost of cement, sand, steel, aggregates, mason, skilled worker, non-skilled work workers the major factors which are considered in cost estimation. As shown in Table.1 six input and one output variables are extracted from the collected dataset [2] in which data of last twenty-three years has been collected from Schedule of rate book (SOR) and general studies.

IV. 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 MATLAB. RMSE, MSE, MAPE, and R2 were calculated and compared for all 15 models to show the best model. It is observed the error from Bayesian Regularization- back propagation shown the best convergence towards minimum error compared to other algorithms. Among those models is 13- 17- 1 model as itspercentage 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.

REFERENCES

1. T.M.S. Elhag "An Artificial Neural System for Cost Estimation Of Construction Projects" 14th Annual ARCOM Conference, 9-11 September 1998, University of Reading. Association of Researchers in Construction Management, Vol. 1,219-26.
2. Van Truong Luu "Neural Network Model for Construction Cost Prediction of Apartment Projects in Vietnam" All content following this page was uploaded by Van Truong Luu on 28 July 2014.
3. Baba ShehuWaziri "Artificial Neural Networks in Construction Engineering and Management" International Journal of Architecture, Engineering and Construction Vol 6, No 1, March 2017,50-60
4. Chinchu Mary Jose "Prediction of Cost of Quality Using Artificial Neural Network In Construction Projects" International Journal of Recent Trends in Engineering & Research (IJRTER) Volume 03, Issue 04; April -2017
5. Atheer Mahmood Al-saadi "Estimating the Optimum Duration of Road Projects Using Neural Network Model" Atheer Mahmood Al-saadi et al. / International Journal of Engineering and Technology (IJET) Vol 9 No 5 Oct-Nov2017
6. Smita K. Magdum "Construction Cost Prediction Using Neural Networks" ISSN: 2229- 6956 (Online) Ictact Journal On Soft Computing, October 2017, Volume: 08, Issue: 01 DOI: 10.21917/ijsc.2017.02161549
7. Bipin Pal "Cost Estimation Model (CEM) of Buildings by ANN (Artificial Neural Networks) – A Review" International Advanced Research Journal in Science, Engineering and Technology ISO 3297:2007 Certified Vol. 5, Issue 2, February2018
8. Mistry. Jignesh. Mukeshchandra,geetha. K. Jayaraj "Implementationof Artificial Neural Network for Recognition of Factors InfluencingLabor Production Rates for Concreting Activities– A Review" IOSR Journal of Mechanical and Civil Engineering (IOSR- JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 15, Issue 5 Ver. IV (Sep. - Oct. 2018), PP07-14
9. Mohammad KabirYaqubi " The Automated Cost Estimation in Construction" International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-8 Issue-7 May,2019
10. Michał Juszczyk "Modelling Construction Site Cost Index Based on Neural Network Ensembles" Cracow University of Technology, 18 March 2019; Published: 20