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Determination of Efficacy of Cost Estimation Models for Building Projects using Artificial Neural Networks, Fuzzy Inference System and Regression Analysis

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Abstract: Construction industry is considered an important sector for the development all over the World. Construction cost Estimation of building construction projects is an essential task in the management of these projects. According to the existing estimating practice, an inconsistency exists between the estimated and actual costs of construction projects especially in developing countries like India. This research aims to compare the cost estimation models produced using various methods to determine their efficacy in producing realistic and accurate cost forecasts of building projects. The various Non-Traditional Methods employed in the study are Regression analysis, Artificial Neural Networks and Fuzzy Inference System. The result of the survey and literature review shows that many factors are affecting construction cost estimation out of which 15 significant factors were identified by conducting t-test using SPSS Software. Data from 116 real executed construction projects in Kerala were collected for the most significant factors to build up models. The Models using ANN and FIS was done in Matlab whereas regression Analysis was carried out in SPSS Software. Effectiveness of the cost models are determined on the basis of RMSE, MAE, MAPE and OI of the models. ANN seems to produce more accurate results and thus more effective than the other methods. One of the main recommendations of this research is to persuade general contracting companies to do construction cost of building projects using special software package.

Keywords Artificial Neural Networks, Cost estimation, Fuzzy Inference system, Matlab, Non- traditional methods, Quantity Rate Analysis, Regression Analysis, SPSS

1. Introduction

A cost estimate is actually the approximation of cost at the early stage of a particular project or work. Accurate cost estimation a construction project is key factor in a project's success. But it is hard to estimate construction costs at the planning stage rapidly and precisely, when drawings, documentation etc... are still incomplete. As such, various techniques have been applied to accurately estimate construction costs at an early stage, when project information is limited. While the various techniques have their problems and consequences, there has been little effort made to determine the best technique in terms of cost estimating performance. [1]. Although it's great importance, the estimating task is neither simple nor straightforward due to the lack of information at this early project stage. Therefore, realistic estimation of construction cost is vital for both successful planning and completion of every construction project. Also in the face of hesitant conditions,
reliable cost estimation become an important basis of information for decision making by all construction parties. Several estimation methods are used in construction practice and the appropriateness of any particular method is usually reliant on the purpose it is used for, the amount of information available at the time of estimation, and the people using it. [2]

The main traditional cost estimation method used for common practice is Quantity Rate Analysis In this method, the entire project is divided into small discrete work items, and a unit rate is established for each item. The unit rate is then multiplied by the required quantity to find the cost for the work item. All costs are added to obtain the Estimated Total Construction Cost. For example, the cost to construct a wall can be precisely determined by finding the number of bricks or laterite required and estimating all costs related to delivering, staging, cutting, installing, and cleaning the brick, along with related units of accessories, such as, reinforcing ties, flashings, etc. [2] Quantity rate analysis is the most accurate means of ascertaining costs based on materials and labor content. In addition to traditional cost estimating approaches, alternative cost

estimation models have been developed and investigated in recent years in an attempt to improve the reliability of cost forecasts in predicting the actual final costs of projects. Many of the developed methods are either algebraic or based on artificial intelligence (neural networks, fuzzy logic,

The major objectives of the research could be listed as follows:

- To explore the existing common practices in cost estimating.
- To identify the significant factors affecting the construction cost.
- To develop cost forecast in cost estimating by various non-traditional methods.
- To compare the cost forecasts produced using various methods - Artificial Neural networks, Regression Analysis and Fuzzy Inference system.
- To determine their efficacy in producing realistic and accurate cost forecasts of building projects

2. Literature Review

Several estimation methods are used in construction practice and the suitability of any particular method is usually dependent on the purpose it is used for, the amount of information available at the time of estimation, and the party using it. Despite the reliance of clients and contractors on available cost estimation and forecasting methods, the actual final costs of construction projects still considerably deviate from their original estimates.(Savas Bayram and Saad Al-Jibouri -2016) [2]. (WisnuIsvara et. al 2015) [3] conducted a study on Hybrid Artificial Intelligence on Schematic Design Stage: RANFIS and CBR-GA and compared the performance of cost estimation models of two different hybrid artificial intelligence approaches: regression analysis-adaptive neuro fuzzy inference system (RANFIS) and case based reasoning-genetic algorithm (CBR- GA) techniques. Models were developed based on the same 50 low-cost apartment project datasets in Indonesia. Tested on another five testing data, the models were proven to perform very well in term of accuracy. Relative important index method was used to found out the most significant factors affecting Time and Cost overruns. The result accomplished from the survey revealed that the major cause for time overruns are material market rate, contract modification, and high level of quality requirement and the major cause for cost overruns are high transportation cost, change in material specification, and escalation of materials price. The study findings highlight the significant factors and some recommendations are given to control time and cost overruns in Indian construction Industry. (S. Shanmugapriya and K subramanian, 2013). [4]

(B.O. Ganiyu and I.K. Zubairu 2010) [5] identified factors contributing to project cost; examine the importance of the factors and develop cost predictive model. Identified six most significant factors to project cost among the design related variables as: Level of design complexity; level of construction complexity; level of technological advancement; percentage of repetitive element; presence of special issues and scope of work. (Gwang-Hee Kim et. al 2013) [1] compared the accuracy of three estimating techniques (regression analysis (RA), neural network (NN), and support vector machine techniques (SVM)) by performing estimations of construction costs. By comparing the accuracy of these techniques using historical cost data, it was found that NN model showed more accurate estimation results than the RA and SVM models. Consequently, it is determined that NN model is most suitable for estimating the cost of school building projects. (Nedal Salah Jameel Al Sheikh, 2013) [6] defined the building factors which is effected the parametric cost estimation. The result of the survey and literature review shows that ten factors are affecting construction cost. The main factors are the area of typical floor, number of stories and the building type. (T.M.S. Elhag and A.H. Boussabaine, 1998) [7] developed two ANN models 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 utilises 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 generalisation capabilities in testing session. Concluded that ANN model I and II managed to achieve average accuracy percentages of 79.3% and 82.2% respectively.

The various algorithms and the solutions to the problems are well balanced pertinent to the fuzzy systems' research projects, labs, and for college- and university-level studies. (Sivanandam et. al, 2007) [8] Fuzzy number is defined as a continuous fuzzy set that contains two properties (1) convexity and (2) normality. The convexity indicates that the membership function has only one distinct peak, while the normality ensures that at least one element in the set has a degree of membership equal to 1.0 at definitely possible Value. These two properties make the concept of fuzzy numbers attractive and naturally suitable for modelling an imprecise quantity such as ''approximately one week'' or ''more or less than five days.'' Theoretically, fuzzy numbers could take various shapes. In modelling real life problems, however, linear approximations such as the trapezoidal and triangular fuzzy numbers are frequently used (Lorterapong and Moselhi 1996) [9].

When regression models are decided to be used, there is always the problem of determining the class of relations between parameters and project costs. It is hard to find the accurate relation between dependent (cost) and independent variables (parameters) when there are multiple cost components. Regression models are more parsimonious when compared to the neural network models. A parsimonious model can be defined as: "a model that fits the data adequately without using any unnecessary parameters" (Sonmez 2004). [10]. A study was conducted by using 217 cases of school building construction projects. Of the cases, 20 cases were used for the testing. The regression model, neural networks model, and support vector machine model with 20 test data gave MAERs of 5.68, 5.27 and 7.48, respectively. Also, the NN model and the RA model had smaller error rates and deviation than that of SVM model. Through the performance, the NN model was the most accurate and reliable of the three models (Gwang-Hee Kim et al 2013) [1].

3. Cost Estimation Techniques

Cost estimation techniques could be broadly classified into Traditional and Non-Traditional methods. Traditional method adopted commonly in practice is the Quantity rate Analysis method. The Non-Traditional methods are either statistical or based on artificial intelligence [2]. In this study, the three Non-traditional methods (Regression Analysis, Artificial Neural Networks and Fuzzy Inference System) are compared. Also these Non-Traditional methods are compared with the Traditional method of cost estimation in predicting the Total Construction cost.

3.1. Regression Analysis

Regression analysis is a statistical process for estimating the relations among variables. It convey the relationship between a dependent variable and one or more independent variables. More specifically, regression analysis helps to recognize how the characteristic value of the dependent variable vary when any one of the independent variables is varied, while the other independent variables are fixed.

Regression analysis is used for prediction of variables. It is also used to understand which among the independent variables are related to the dependent variable, and to investigate the forms of these relationships.

By using RA, the model of the cause and consequence relationship between dependent variable and independent variable(s) can be determined and estimation can be performed. RA is mainly divided into two groups: linear regression analysis (LRA) and nonlinear regression analysis (NLRA). The purpose of linear regression is to establish the nearby line to the data, while nonlinear regression is a more general technique to fit a curve through the data. According to the number of independent variables, LRA can be divided into two groups: simple and multiple. Simple linear regression analysis (SLRA) is used to estimate the dependent variable with only one independent variable, while multiple linear regression analysis (MLRA) is used to estimate the dependent variable by using two or more independent variables.

For Simple Linear Regression Analysis,

$$y = a + bx \quad [2] \qquad (1)$$

For Multiple Linear Regression Analysis,

$$y = a + bx1 + bx2 + bx2 + \ldots \quad [2] \qquad (2)$$

Where,

- y is the dependent variable
- x,x1,x2..... are the independent variables
- a and b are constants

Regression Analysis could be done using many software. The commonly used among them are SPSS, Minitab, Python, R, Excel etc... [1]

3.2. Artificial Neural Networks

Artificial Neural Networks (ANN) are also referred to as connectionist systems. NN is a computer system that simulates the learning process of the human brain based on a simplified model of the biological neurons in the human brain and the relations between them. Neural Networks are based on a large collection of neural units loosely modeling like brain solves problems with huge clusters of biological neurons connected by axons. Each neural unit is connected with many others, and links can be enforcing or inhibitory in their effect on the activation state of connected neural units. Each individual neural unit may have a summation function which combines the values of all its inputs together.

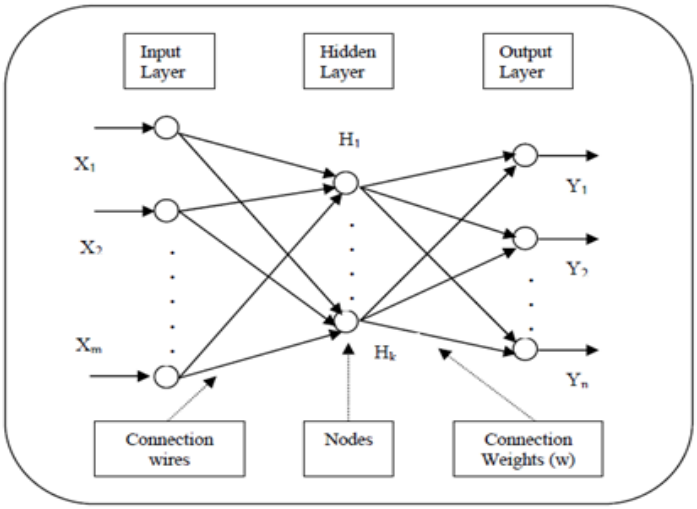

Figure 1. A Simple Artificial Neural Network Structure [7-1]

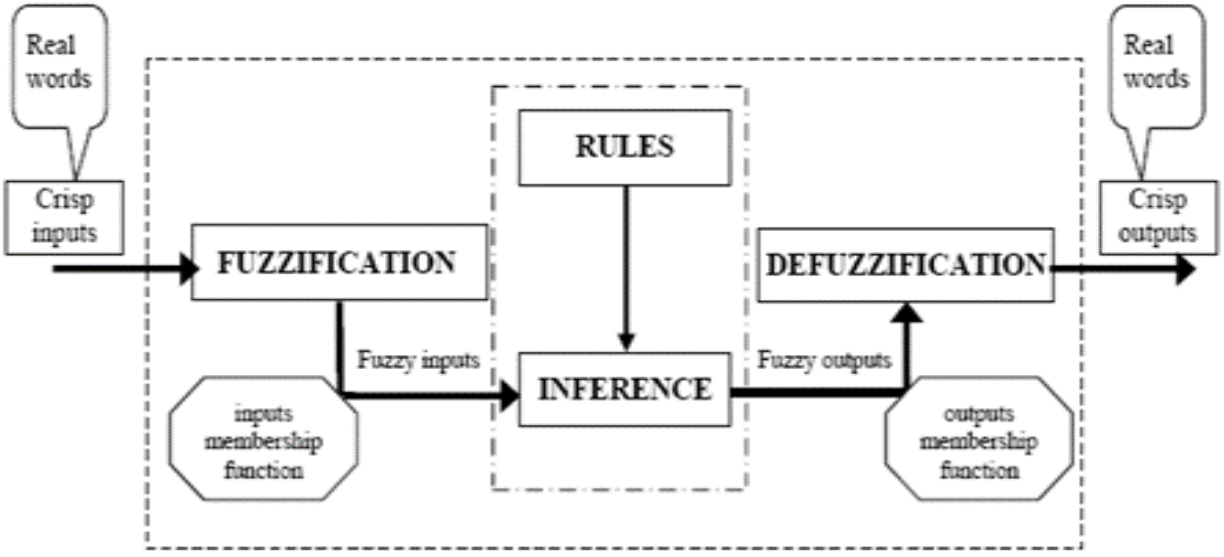

Figure 2. A Fuzzy logic system [6]

Basically, the network consists of several layers, including an input layer, a hidden layer, and an output layer, and each layer contains neurons. [Figure 1] Neurons determine the optimum value through a summation and transfer function. The set of inputs, which is the outputs from another neuron in input layers, are delivered by neurons. Each input data is multiplied by the connection weight, and then the weighted inputs provide output value, which is modified by the transfer function. [1]

3.3. Fuzzy Inference System

Construction applications are increasingly using computer modeling techniques to help make decisions and estimate costs, performance, quality or time. Fuzzy set theory and fuzzy expert systems are used increasingly in situations where little deterministic data are available. Fuzzy logic was invented by Zadeh in 1965, and has got many applications in many sectors of industry. "Fuzzy set theory was originally devised to mode 1 uncertainty associated with human perception or subjective probability judgments". Fuzzy set theory has been used for construction management applications such as risk assessment and pricing construction risks. It can also be used for project control issues such as scheduling estimating project network analysis cash flow analysis evaluating alternative construction technology, Crane selection and assisting in selecting corrective actions when problems arise on the construction site etc...

Fuzzy control is the most important application in fuzzy theory. Using a procedure originated by Ebrahim Mamdani in the late 70s, three steps are taken to create a fuzzy

controlled machine:

- Fuzzification (Using membership functions to graphically describe a situation)
- Rule evaluation (Application of fuzzy rules)
- Defuzzification (Obtaining the crisp or actual results) [11]

4. Research Methodology

The research methodology for present study has adopted questionnaire survey to identify significant factors affecting construction cost estimation in building projects of Kerala. To identify factors literature study was carried out. A structured Interview was carried out in order to identify the problems with current estimation methods. 42 factors affecting Construction cost Estimation was identified through Questionnaire survey with 64 experts in the construction industry, out of which 15 significant factors identified by t-test using SPSS Software are used the analysis.

4.1. Data Collection

Second set of data collection was done based on the selected 15 significant factors affecting construction cost estimation. Data was collected from 116 real executed completed building projects in Kerala (especially in Malabar Region). This data serves as the input data for the development of construction cost estimation models using Regression Analysis, Artificial Neural Network and Fuzzy Inference System. The identified factors are:

Table 1. Data Collection

Factors	Range
Gross Floor Area (m^2)	65-62245
Total Duration (months)	8-48
Cost of Foundation (INR)	2lakh-12 cr.
Number of Storeys	1-7
Floor Height (m)	3-6.2
Percentage of Repetitive Elements (%)	15-70

Table 2. Frequencies of conditional factors

Factors	Conditions	Freq.
Geographic Conditions	Flat	89
	Gentle Sloped	19
	Steep	8
Ground Conditions	Soft	40
	Moderate	57
	Hard	11
	Free	8
Type of Foundation	RR	65
	Isolated	19
	Strap	2
	Column	20
	Pile	9
	Combined	1
Type of Building	Residential	65
	Commercial	21
	Educational	7
	Office	7
	Others	16
Market conditions	Stagnation	44
	Stable	69
	Boost	3
Design Complexity	Not Complex	53
	Medium Complex	40
	Highly Complex	23
Quality of Work	High	76
	Medium	40
	Low	0
Changes in Materials	Yes	77
	No	39
Unforeseen items/Conditions	Yes	64
	No	52
Output	**Construction Cost(INR)**	

4.2. Model Development

The data collected are analysed by Correlation analysis in order to identify the degree of relation between the input variables and output variable.

Three cost Estimation Models are then developed using Artificial Neural Networks, Fuzzy Inference System and Regression Analysis. Linear Regression Analysis is done using SPSS 16 software whereas Artificial Neural Network and Fuzzy System are done using Matlab R2015b software. All factors are assigned with numerical values in order to make the model development easier for Regression Analysis and Artificial Neural Networks. For the development of Fuzzy models, certain ranges are fixed in order to add the Membership functions and thereby adding rules.

Artificial Neural Network model is developed in Matlab R2015b using the Neural fitting tool in Matlab. The developed neural network is trained with Levenberg-Marquardt back propagation algorithm (trainlm). Construction cost estimation model using regression analysis is developed using Multiple-Linear Regression Analysis (MLRA) [Equation (2)] in SPSS16. For developing the fuzzy models, Mamdani fuzzy logic designer is used. The ranges of output and input variables are fixed within the range of 0-1 (normalization). Membership functions are then added for each input variable as well as the output variable. Triangular Membership (trimf) function is selected for the easiness of model development. Rules are then added according to the membership functions assigned.

4.3. Efficacy Determination

Generally, the performance of a cost estimating model is determined by measuring its bias, consistency, and accuracy. Measures of bias, consistency, and accuracy are concerned with the difference in the average between the actual costs and the estimated costs, considering both the degree of variation around the average, and the combination with bias and consistency [1]. Here, the efficacy of the cost estimation models are determined by means of standard error measures RMSE (Root Mean square Error), Mean absolute Error(MAE), Mean Absolute Percentage Error(MAPE) and the OI (Overall Index) of the Model Performance. [2]

These measures are determined based on the differences between the final actual cost of each of the control projects and its cost forecasts produced by the different approaches using certain equations [2]

Table 3. Error Rates of Different Models

Sl No.	Actual Cost (INR)	QRA	Error Rate (%)	ANN	Error Rate (%)	RA	Error Rate (%)	FIS	Error Rate (%)
1	21000000	15000000	28.57	20435000	2.69	31000000	47.62	20000000	4.76
2	5275000	4000000	24.17	4846800	8.12	6882953	30.48	5000000	5.21
3	3240000	3900000	20.37	2440700	24.67	3012994	7.01	3000000	7.41
4	2780000	2000000	28.06	2117000	23.85	2332605	16.09	3000000	7.91
5	13400000	10000000	25.37	12765000	4.74	12261794	8.49	20000000	49.25
6	45500000	40000000	12.09	44090000	3.10	37786885	16.95	40000000	12.09
7	19400000	15000000	22.68	22733000	17.18	18920798	2.47	20000000	3.09
8	3558000	3200000	10.06	3350100	5.84	4588750	28.97	3000000	15.68
9	2876000	2800000	2.64	3560800	23.81	3040333	5.71	3000000	4.31
10	4470000	4000000	10.51	3955200	11.52	6625917	48.23	5000000	11.86
11	55650000	50000000	10.15	54305000	2.42	60847942	9.34	60000000	7.82
12	3520000	3200000	9.09	3379900	3.98	4561770	29.60	3000000	14.77

5. Results and Discussions

For comparing the models another set of data from 12 real executed completed building projects are collected. The results of comparison of the output of cost models are shown in Figure 3. The error rates of each project is calculated for all the models as well as for the cost estimated using quantity rate analysis. Table 3 shows the error rate of different models.

Table 4. Error Comparison of Different Models

	QRA	ANN	RA	FIS
RMSE	3319380	1214053	4058898	2815910
MAE	2407417	893842	2600299	1709750
MAPE	16.98	10.99	20.91	12.01
OI	0.957	0.987	0.945	0.965

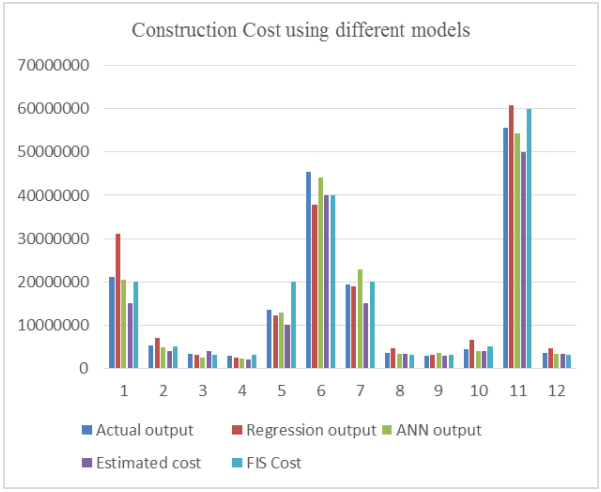

Figure 3. Graphical Representation of Cost of Different Models

The RMSE values of different models are plotted as follows:

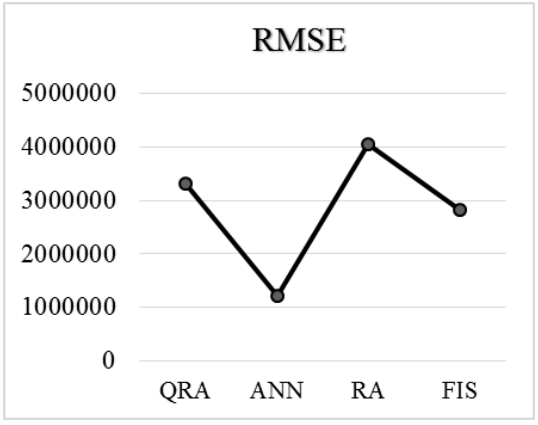

Figure 4. RMSE Values of Different Models

The lesser the RMSE value, Greater the Efficacy of the model. From the above figure it is clear that the Artificial Neural network model gives the least Root Mean Square Error value and hence it seems to be more effective in terms of RMSE than that of other models. The next least value is for the Fuzzy Model and then comes the traditional QRA and the highest RMSE value is for the Regression Model. Hence Artificial neural Network Model seems to be effective.

The MAE values of different models are plotted as follows:

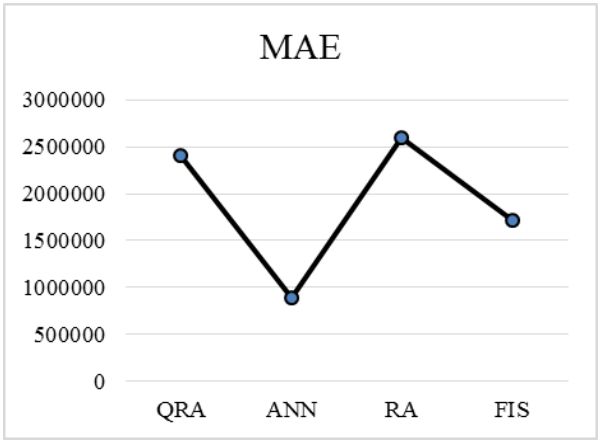

Figure 5. MAE Values of Different Models

The MAPE values of different models are plotted in Figure 6. Mean Absolute Percentage Error value gives the total error percentage of the models. Here, the Regression Model shows high error rate i.e. 20.91%, Quantity Rate analysis gives error value of 16.98% and Fuzzy Model shows error value of 12.01%. Here the lowest error value is shown by the Artificial Neural Network Model i.e. 10.99% and hence shows an effective result than all other models.

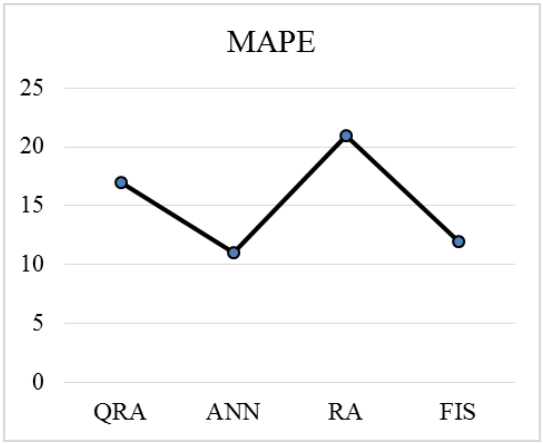

Figure 6. MAPE Values of Different Models

The Overall Index of the model performance gives a clear idea of the performance of each cost estimation model to be effective in predicting the construction cost of building projects than all other error values. From Figure 7, it is clear that the overall index is high for the ANN model i.e. 0.987, then comes the FIS model with 0.965 OI value. The traditional Quantity Rate Analysis shows an OI value of 0.957 and the least OI value is for the Regression Analysis Model. Hence ANN seems to be effective than all other three models.

6. Conclusions

Regression models for estimating the construction project cost were developed in SPSS and neural network models and fuzzy models for estimating the same were developed in MATLAB. It has proven that Artificial Neural Network model is found to be more reliable and effective than the regression models, fuzzy inference system and even traditional method of estimation.. Regression is the method of statistical calculation to predict a value in terms of the past information. Regression analysis performed in this attempt developed based on the historical data. Regression models were developed with the help of SPSS. Artificial Neural Network is a machine learning technique suitable for complex cases requiring large number of parameters to be considered in parallel. Models were developed with the help of MATLAB. The models were trained and tested using the data collected from different projects. Fuzzy Inference system is also a technique suitable for complex cases requiring large number of parameters to be considered in parallel. Models were developed with the help of MATLAB. The traditional and non-traditional method was compared using the standard error like Root Mean Square Error, Mean absolute Error, Mean Absolute Percentage Error and also using Overall Index of the Model Performance. Error rates are lower for

Artificial Neural Network Model. Also it shows a high value of Overall Index of the model performance. The Error percentage could be up to -25% to +50%. The error percentage of ANN model is 10.99% which is a low value. Hence, at the current state of building construction in the region, ANN is most suitable for predicting the construction cost.

The characteristics of best model for construction cost estimate using ANN is given below.

- Number of Input Nodes = 15
- Number of Hidden nodes = 12
- Number of output Nodes = 1
- Mean Absolute percentage Error = 10.99%
- Overall Index = 0.987

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