DEVELOPMENT OF A NEURAL NETWORK BASED MODEL FOR CONSTRUCTION PROJECT MANAGEMENT EFFECTIVENESS

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Abstract - An artificial neural network based methodology is applied for predicting the level of organizational effectiveness in a construction firm. The methodology uses the competing value approach to identify 12 variables. The historical data of construction projects performance have been used to build the neural network model. Based on these factors, the construction projects management effectiveness model was established. The model can serve as the framework for further development of the construction management decision support system.

Key words: Artificial neural network**,** construction management

INTRODUCTION

In the competitive nature of construction, industry and its heuristic problem-solving needs, among other reasons, have contributed to the development of some advanced decision-making tools. Research in artificial intelligence (AI), a branch of computer science, has provided more suitable tools to the construction industry. Since its initial development, the Artificial Intelligence has found large applicability in the field of engineering. In particular, the so-called soft computing methods have been shown to be very effective in the analysis and solution of construction engineering problems. However, the performance of these systems during the last decade is far from ideal. Neural networks research in AI has recently provided powerful systems that work as a supplement or a complement to such conventional expert systems. In this paper, neural networks are introduced as a promising management tool that can enhance current automation efforts in the construction industry, including its applications in construction engineering. The approach of artificial neural network is one of the empirical modelling technique that allows evaluation of the construction projects management effectiveness and to determine the factors that influence the project effectiveness in terms of budget performance.

ARTIFICIAL NEURAL NETWORKS

In a broad sense, the artificial neural network (ANN) itself is a model because the topology and transfer functions of the nodes are usually formulated to match the current problem. Many network architectures have been developed for various applications. The performance of a neural network depends on its architecture and their parameter settings. There are many parameters governing the architecture of the neural network including the number of layers, the number of nodes in each layer, and the transfer function in each node, learning algorithm parameters and the weights which determine the connectivity between nodes. There is no clearly defined theory which allows for the calculation of the ideal parameter settings and as a rule even slight parameter changes can cause major variations in the behaviour of almost all networks. So far, the technique in the use of the neural network for predicting software cost estimation is back propagation trained multilayered feed forward networks with sigmoidal activation function. But, there are some limitations that prevent it from being accepted as common practice in construction management effectiveness. The main reason for slow convergence in back propagation is the sigmoid activation function used in its hidden and output layer units. Furthermore, inappropriate selection of network patterns and learning rules may cause serious difficulties in network performance and training. The problem at hand decides the number of layers and number of nodes in the layers and the learning algorithm as well. However, the guiding criterion is to select the minimum nodes which would not impair the network performance so that memory demand for storing the weights can be kept minimal. So, the number of layers and nodes should be minimized to amplify the performance. A proper selection of tuning parameters such as momentum factor, learning coefficient are required for efficient learning and designing of stable network.

LITERATURE REVIEW

Chua et al. (1997) proposed a neural network approach to identify the key management factors that affect budget performance in a project. This approach allowed the model to be built even if the functional interrelationships between input factors and output performance could not be clearly defined. Altogether eight key determining factors were identified covering areas related to the project manager, project team, and planning and control efforts, namely: number of organizational levels between project manager and craftsmen, project manager experience on similar technical scope, detailed design complete at start of construction, constructability program, project team turnover rate, frequency of control meetings during construction, frequency of budget updates, and control system budget. The model can be used to evaluate various management strategies and thus resources can be effectively deployed to strengthen these aspects of project management.

Parminder Kaur (2016) proposed an ANN model that was prepared in order to predict the duration of any ongoing project in addition to conventional techniques of project planning. A large number of trials were applied for model training. The absolute variance of model's results varies from 1.7% to 2.6% which is less than variance calculated by use of PERT network technique (3.8 to 7.8%) in cases studied. Therefore the model testing is successfully passed and it can be concluded that Artificial Neural Networks are an effective project management tool that can be used to effectively predict the project duration and hence prevent scheduling and project duration overruns.

Megha Jain, KK Pathak (2014) concluded that ANNs have been successfully applied to many construction engineering areas like prediction, risk analysis, decision-making, resources optimization, classification, and selection etc. Based on the results of case studies, it is evident that ANNs perform better than, or at par to the conventional methods and also found that ANN have a number of significant benefits that make them a powerful and practical tool for solving many problems in the field of construction engineering and are expected to be applicable in future.

Baba Shehu Waziri, Kabir Bala and Shehu Ahmadu Bustani (2017) 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 study provides comprehensive repute of ANN in construction engineering and management for application in different areas for improved accuracy and reliable predictions.

QUESTIONNAIRE SURVEY AND DATA ANALYSIS

A questionnaire was developed to collect data from past projects to be used in developing a predictive model. It was categorized into profile of the respondent and various factors which improve organizational performance. Questions in the respondent profile were created to collect information such as name of company, contact information, type of organization, projects per year and size of projects. The framework for the list of construction management effectiveness factors covering areas related to project manager, project team, project planning, organization and control, safety management , material management, financial Planning was selected from the research conducted by Jaselskis and Ashley (1991), Kanchana Priyadarshani (2003), adnan enshassi(2009), aparna shruthi E (2017). However, the actuality of each construction management factor was retested by interviewing construction management practitioners, engineers, and contractors and the approach was modified according to the interviewers opinion. Construction project management effectiveness factors described in Table 1 served as the independent input variables.

Table 1: Construction Project Management Effectiveness Factor

Category	**Project Management Factor**	**Measure**
Project manager (PM)	PM Meetings	Number/month
	PM time devoted	hours/day
	PM field visit	Number/month
	PM Subordinates	Number
	PM education level	Years
	PM experience as a Project Manager	Number of projects
	PM experience other than as PM	Number of projects
Project team	Monetary incentive to designer	% of design contract

	Monetary incentive to engineer	% of design contract
	Monetary incentive to contractor	% of design contract
	Monetary incentive to sub contractor	% of design contract
Planning	Design complete at construction start	Percent
	Budget contingency	Percent
	Modularisation	% of total constriction cost
Organisation and control	Progress inspections	Number/month
	Quality inspections	Number/month
	Control system budget	Percent of total budget
	Schedule updates	Number/year
	Budget updates	Number/year
Safety management	Safety meetings	Number/month
	Accidents rate	Number/project
	Site safety inspection and supervision	Number/month
Material management	Inspection & documentation of materials	Number/month
	Material Requirement Planning	Number/month
Financial Planning	Meetings related to fund flow	Number/month
	Percentage of bank loans	Percent
	Cash flow statement	Number/month
	Percentage of advances from customer	Per Month

Construction cost variation criterion was used to measure construction project management effectiveness. The output variable of that model - construction project cost variation *Q*- was calculated by equation:

$$Q = \frac{PI - FI}{PI} . 100 \text{ .... (1)}$$

where *PI* - estimated construction project cost; *FI* - actual construction project cost.

The present study is based on a set of data obtained in a questionnaire survey on construction project management effectiveness factors from construction companies mostly in Amravati region and Yavatmal region. Personal contact was the major communication tool used to get organizations participated in the study. The interviewees were construction and project managers, engineers, consultant, and contractors. Information was collected on 99 completed projects. But only information on 66 completed projects were used for training and testing purpose. Then the whole data set of 66 projects was divided into two subsets: training and testing. The neural network model was trained with 54 project samples and retested with 12 project samples. The input data - project management factors - were classified into seven groups and the output data -the percentage of the construction cost variation in loss or profit - were classified into five groups (Table 2).

Table 2: Classification of project cost variation

Range of predicted project cost variation Q	Class description
Q > +10%	Very good
+3% < Q ≤ +10%	Good
−3% ≤ Q ≤ +3%	Average
−10% ≤ Q < −3%	Poor
Q< −10%	Very poor

MODEL DEVELOPMENT

The construction projects management effectiveness neural network model had been developed using the NEURAL NETWORKS TOOLBOX by MATLAB. Preparation of the training data and statistical computations had been performed by applying Microsoft Excel.

In our case we have used a ratio of 70% data for training and 30 % data for testing, where 54 samples has been train and 12 samples has been tested and same for the validation.

The neural network chosen in the present study is multilayered with neurons in all layers fully connected in the feed forward manner. Sigmoid function is used as an activation function. The number of neurons in the input and output layer was decided by the number of input and output variables of the construction project management effectiveness neural network. Thus, the input layer had 28 neurons and the output layer had 5 neurons, representing five classes of the construction cost variation. One hidden layer is chosen in which the number of neurons is decided during the training process by trial and error (fig 2). The neural network was trained to solve the classification task by applying resilient back propagation learning algorithm.

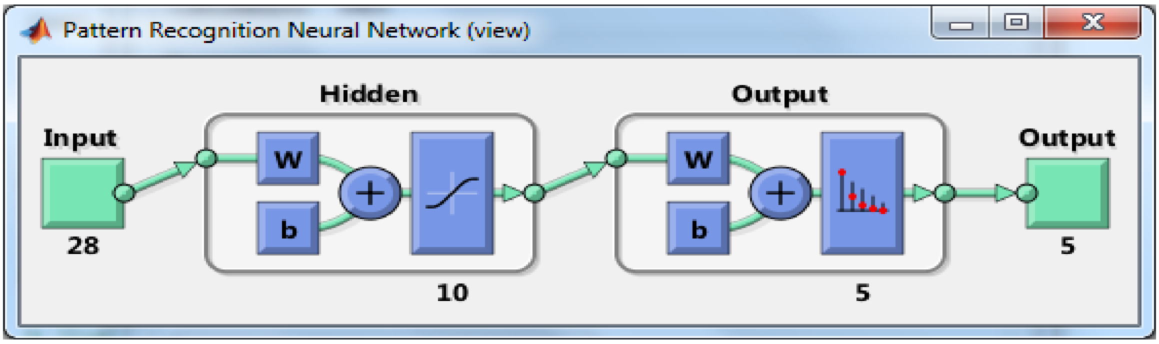

Figure 2 Network building for 28 inputs

All construction management effectiveness factors were incorporated into the model at the first stage of model development. The initial network model comprised 28 neurons in the input layer with 1 neurons in the hidden layer and 5 neurons in the output layer. However, experimentation with an initial model that included all 28 variables resulted in a model with poor performance, thus indicating that including all variables makes the model less sensitive to each of them.

Many experiments with various network architectures were performed during training in order to arrive at the best-trained network. The insignificant factors were trimmed from the network at the stage of model development. This was done gradually by eliminating the least important factors. Based on the classification error, the final neural network model was built with 12 neurons in the input layer, 4 neurons in hidden layer and 5 neurons in the output layer.

CONCLUSIONS

A neural network for predicting construction project management effectiveness for the construction firm is developed. Twelve variables were identified to predict effectiveness. The network is a valuable practical tool that can give management of a construction firm operating in institutional and commercial construction a preproject view of their performance. To improve the performance of the network, significant variables through statistical analysis are identified, and then these variables are used in the input and hidden layers of the ANN. This has resulted in obtaining a simple and computationally efficient network that can predict organizational effectiveness of the construction firm.

The established neural network model can be used during competitive bidding process to evaluate management risk of construction project and predict construction budget performance. The model allows the construction project managers to focus on the key success factors and reduce the level of construction risk. The model can serve as the framework for further development of the construction management decision support system.

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