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Evaluating Organizational Effectiveness of Construction Industry Using Artificial Neural Networks

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***Abstract* – In the construction industry we are struggling in selecting the best organization in the pretender stages. We select organization on the basis of lowest bid offered in a tender for particular contract having only the knowledge of reputation of work and the rate offered for the tender by the organization at the least we offer the contract to the organization. We do not pay much attention towards the methodologies adopted in solving the problems that arise the various sector in organization. So, there is an urge in finding out the functional efficiency of an organization. In the present scenario experts are trying out better solutions or enhancing organizational effectiveness. Concepts such as total quality management, re-engineering, partnering, conformance to ISO standards, and other emerging management strategies are making headlines. However all of the techniques stress measurement and continuous assessments how the firm organized as important steps in improvement. Therefore it is clearly becoming essential for construction firms to develop valid methods of assessing and prediction their level of organizational effectiveness and hence achieve consistency in the projects performance. For that we need a novel approach for assessing the efficacy of the system used. In any organization the quality and the productivity depends upon the effectiveness of the systems implemented in the organization. So, it becomes necessary for evaluating the functional capability of the organization. We propose Artificial Neural Network (ANN) as decision aiding tool for evaluating the effectiveness and thereby reducing the flaws incorporated by the other techniques in use.**

***Keywords :* Organizational Effectiveness, Artificial Neural Network, Feed forward network, Linear transfer function.**

I. Introduction

Over the recent years application of artificial neural networks (ANN) has undergone much investigation in the various fields of Civil Engineering. This interest has been motivated by the complex nature of systems involved in different fields of Civil Engineering like Structural Engineering, Water Resources Engineering, Construction Engineering and so on. In the present study, it is proposed to use ANN for the evaluation of organization effectiveness because of the dynamic behaviour of the management system application in construction industry. In recent years, ANNs have found number of application in the area of construction such as labour productivity, resources planning, product and recovery, performance monitoring, and customer rating analysis (Ming *et al* 2000, Morshe*d et al* 1998) [1,2].

The ability to learn and generalize “knowledge” from sufficient data pairs make it possible for an ANN to solve large - scale complex problem such as pattern recognition, non linear modeling, classification and others which find application in construction industry. A significant growth in the interest of this computation mechanism has occurred since Rumelhart et al (1986) [3] developed a mathematically vigorous theoretical framework for neural networks. Since then, ANNs have found increasing use in diverse disciplines ranging over perhaps all branches of engineering and technology. Researchers in construction have shown serious interest in this computation tool during the last decade. An attractive feature of ANNs is their ability to extract the relation between the inputs and outputs of a process without the physics being explicitly provided.

II. Study of Construction Industry

The effectiveness of the construction industry influenced by many factors such as, type and size of organization, structure and function of organization, functional elements and other parameters. The estimation of such variables is often complex and non-linear problem, making it suitable for ANN application. It is very important to ensure the process and control of the organization. Some of the factors affect the real time process are

- The great complexity and variability in the functioning elements
- Lack of on line measurement tools
- Unpredictability of the resources availability
- Dynamic state of the construction methodology

The ANN based modeling method id concerned with extracting useful patterns ore relationships between different variables by means of analyzing the historical data base of the organization.

III. Organizational Management A Descriptive Case Study

Organization structure, strategy and cultural factors mainly determine the level of organization effectiveness of the construction firm. The above said factors can be generalize into number of categories.

- Person oriented process
- Organization flexibility
- Rules and regulation
- Reliability of engineering working elements
- Quality control engineering
- Quality assurance
- Inspection and testing
- Total Quality Management

These categories can be subdivided into number of variables like organization, planning and designing, execution, time, quality, cost, records, maintenance, risk analysis, and communication. A questionnaire with ten different variables which measures the efficiency of the organization was prepared by the Expert Information System. Every set of variables has 3-5 questions in a row and the maximum of 100 points incorporated with each variable. An organization can score 1000 points at the maximum. Effectiveness of the organization can be measured by the overall scores pursued by the organization. The aforementioned questionnaire is given to the consultancy engineers, contractors, architects, well established organization in the field of construction and response was collected and evaluated. Using these scores as a historical database for feeding the network and the interrelationship between variables have been analyzed to find the effectiveness of the organization.

IV. Artificial Neural Network

Feed-forward networks have proven to be very powerful computation tools that excel in pattern recognition and function approximation. The general structure of a feed-forward neural network is shown in Fig.1. The node in input layer receives the inputs of the model and they flow through the network and produce outputs at nodes in the output layer. The working principle of feed-forward neural network is available elsewhere. Mathematically, a three- layer neural network with I input nodes, J hidden nodes in a hidden layer, and k output nodes, can be expressed as:

$$O_k = f_1\left[\sum_{j=1}^{j} w_{jk}^{ho} \; f_2\left[\sum_{i=1}^{i} w_{ij}^{ih} x_i + b_j^{h}\right] + b_k^{o}\right]$$

Where O_k is the output from the k^{th} node of the output layer; x_i is the input to the network at node i of the input layer w_{ij}^{ih} ; is weight between i^{th} node of input layer and j^{th} node hidden layer; b_j^{h} is the bias term added to the j^{th} hidden w_{jk}^{ho} node; j^{th} is weight between j^{th} node of hidden layer and k^{th} node of output layer and b_k^{o} is the bias term added to the k^{th} output node.

In this paper, the first-order method was used to weed out the useless input variables. In a three layer perceptron with I inputs J hidden nodes and K output layers, the output at k^{th} output node can be written as

$$y_k = \frac{1}{1+e^{-sum_k^o}}$$

Where $$sum_k^o = \sum_{j=1}^{j} w_{jk}^{ho} h_j + b_k^o$$

$$h_j = \frac{1}{1+e^{-sum_j^h}}$$

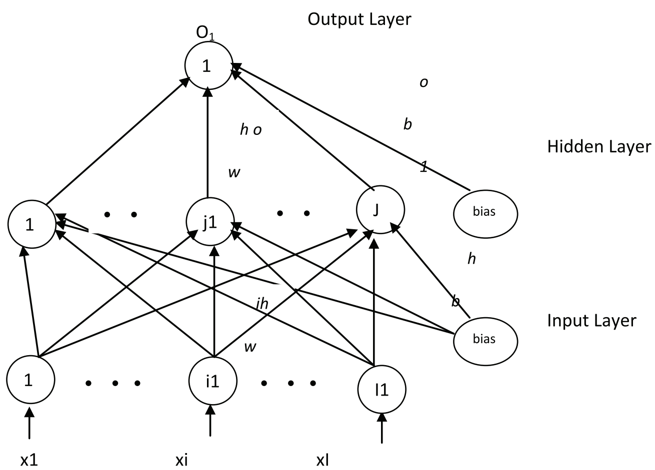

Fig.1 Architecture of three-layer feed forward network

$$sum_j^h = \sum_{i=1}^{i} w_{ij}^{ih} x_i + b$$

w_{ij}^{ih} is weight between i^{th} node of input layer and j^{th} node of hidden layer,

b_j^h is the bias term added to the j^{th} hidden node,

w_{jk}^{ho} is weight between j^{th} node of hidden layer and k^{th} node of output layer

and

b_k^o is the bias term added to the k^{th} output node,

The differentiation of $f(x) = 1 / (1+ e^{-x})$ with respect to x is $f'(x) = e^{-x} / (1+ e^{-x})^2$. Thus

$$\frac{\delta y_k}{\delta x_i} = \frac{e^{-sum_k^o}}{\left[1+e^{-sum_k^o}\right]^2} \text{ x } \frac{\delta\, sum_k^o}{\delta x}$$

$$= \frac{e^{-\ \ _k^o}}{\left[1+e^{-sum_k^o}\right]^2} \text{ x } \sum_{j=1}^{j} w_{jk}^{h} \text{ x } \frac{e^{-sum_j^h}}{\left[1+e^{-sum_j^h}\right]^2} \text{ x } w^{ih}$$

$\frac{\delta y_k}{\delta x_i}$ is named as Relative Strength Effect (RSE) by Kim *et al.* (2001). If linear activation function is used at output layer the equation becomes

$$\frac{\delta y_k}{\delta x_i} = \sum_{j=1}^{j} w_{jk}^{h} \text{ x } \frac{e^{-sum_j^h}}{\left[1+e^{-sum_j^h}\right]^2} \text{ x } w_{ij}^{ih}$$

This is a parameter that could be used to measure the relative importance of inputs in contributing to predict outputs. The larger the absolute value, the greater is the contribution. When $\frac{\delta y_k}{\delta x_i}$ is positive, the increase in input, increases the output, and if it is negative an increase in input causes a fall in output.

V. Results and Discussion

The data base used in this study is pertaining from various contractors, consultancy engineers, construction firms, architects, and experts in the construction industry. It contains 75 records collected by questionnaires and credit point evaluation. 50 records were used for training and he remaining records were used for testing. To predict Organizational Effectiveness (OE) we were used following input variables: organization, planning, and designing, execution, time, quality, cost, records, maintenance, risk analysis, and communication. The network was trained with 7 hidden nods in a single hidden layer. Linear transfer function is used at output layer and logistic sigmoidal function was used at hidden layer. All the input and output data are normalized by dividing the data by the maximum in the field. The correlation coefficient between the input and corresponding output is 0.96936.

Initially the model was trained with 10 inputs. After training, the sum of squared error has evaluated. Depending upon the error we have removed the input list and a next model was set for further study. Deciding the variables to be removed is based on judgment and no specific rule is followed. The history of input variable elimination of the study is shown in Table I When removing a variable, sometimes the correlation between OE and predicted OE is slightly falls down. A very small fall was accepted. In the present case, starting from 10 inputs, the final model was with 4 inputs. Throughout the analysis 7 hidden nodes were used. After fixing 4 inputs, sensitivity tests were conducted on number of hidden nodes. A minimum of six numbers of hidden nodes provides best result.

Table I elimination of input hierarchy

Model	No. of Inputs	Removed Inputs	Sum of Squared Errors	Correlation between OE and Predicted OE		
				Training	Testing	Overall
1	10	Nil	0.2832	0.97073	0.96709	0.96936
2	9	Execution	0.2864	0.93486	0.97114	0.92944
3	8	Cost	0.2921	0.96776	0.95440	0.96511
4	7	Organization	0.2973	0.96376	0.95683	0.96276
5	6	Communication	0.3002	0.96781	0.93878	0.96328
6	5	Maintenance	0.3088	0.95810	0.93144	0.95280
7	4	Records	0.3169	0.94327	0.84641	0.92493

VI. Conclusion

The main aim of this proposed study is to identify the effectiveness of the construction industry in the pretender stage itself. But it is obvious that no company will project their flaws during the tendering stage. Henceforth the current study established a mathematical model which identifies the functional capability of an organization using the correlation between historical database collected by the expert information system and a very minimal parameter about the organization which can be derived from the tender document itself. The current research proposed a model which provides 92.49% of accuracy with just 4 inputs out of 10 selected functional variables of the organization. Hence this mathematical model will enable us to evaluate the organization based on the available limited functional parameters.

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