

ESTABLISHMENT OF PREDICTIVE MODEL USING ANN FOR LABOR PRODUCTIVITY IN SURAT

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Abstract— We know that construction is the world's largest and most challenging industry. Labor productivity and poor productivity are being faced by most of developing countries. The main aim of this Paper is to identify critical factor which affects construction labor productivity and to use them for developing a predictive model. This paper presents the factors which affect the labor productivity for the residential and commercial buildings within Surat city, Gujarat. By literature review total 47 factors were finalized that affects the labor productivity within the scope of work and distributed in eight main categories as: Management, Supervision, Safety program and motivation, Technical excellence and site layout, Proper planning and schedule, Labor competence, Effective communication and language understanding, and External condition. The analysis to find out the most influencing factors has been done using the Mean Variance Method through the SPSS tool. After finding top 11 factors, an ANN models is developed by using MATLAB software to predict labor productivity. Amongst various trials, we found that 85%-15% FFDTD is the best model for the prediction. At last, we took four case studies for validation of ANN Model on ongoing projects in Surat which has shown the satisfactory results in predicting the productivity.

Index Terms—Labor productivity, Commercial and Residential, ANN Model.

I. INTRODUCTION

The concept of "Productivity" has multiple views for different people. It depends on the one who is explaining productivity, whether he is a, accountant, business person, economist, writer, sportsmen, industrial engineer, or construction manager, you will get a variety of different meaning of the term Productivity. For someone and others, productivity is relating to production rate, efficiency, effectiveness or merely the combination of all these.

In the concern of construction sector, the concept of the term productivity varies with its application to different areas. The term productivity mostly refers to the output produced per unit input. Defined labor productivity as the "ratio of the output quantities to the input work hours".

Labor Productivity = Output Quantity / Work Hours

Labor Productivity = Output / Labor cost.

In developing countries, among various problems in construction industry, the productivity is one of most daunting problem. And in India the construction industry having share of 8% of its GDP and provides employment to around 35 million people.

Labor is one of the dominant human resource in the construction industry. Labor productivity usually deals with manpower in terms of labor cost to the quantity of outputs produced. Labor cost generally make up 30 to 50% of overall project cost in construction phase. Since labor productivity is among the measures of the economy of a project, improving the efficiency over labor productivity and its related factors will improve the overall productivity. In construction sector, many of the activities are involved which depends only on human resource, so an effective utilization and controlled management of labor for each activity is very important. In spite of all the technological advancements and education, India is lacking in the effective labour productivity. So we can say the combination of Construction productivity and labor productivity are effective tools to determine the gain and loss of construction business.

Variations in construction labor productivity is a slow process and are the result of multiple factors and experiences. Through the productivity models, the relationship amongst the influential factors and the resulting productivity can be quantified for estimating, scheduling and planning the future projects, these models are efficiently helpful in decision making. To predict and analyze the relationship between key influential factors and labor productivity, a variety of modeling techniques have been developed viz. the expectancy model, expert systems, statistical & regression models, action-response model, and artificial neural networks (ANNs).

The action-response models and expectancy model both contribute to understanding the variations in productivity; however, the models is ineffective to quantify the influence of multiple factors on construction productivity. Regression models are generally limited by the number of influencing factors that can be included and their capability of measuring the combined effect of the influencing factors. Expert systems in general have very limited capabilities in terms of identifying a mapping function and generalizing solutions. Artificial neural networks represent a type of computing based on the way that the brain performs computations. Developing a model for measuring and predicting construction labor productivity requires performing complex mapping of influencing factors to labor productivity. Considering that a multitude of factors simultaneously affect labor productivity, this mapping includes quantification of the effects of factors on labor productivity and quantification of the interactions among the factors. This task is analogous to that performed by some of the neural network models. Artificial neural networks have the ability to learn from experience for improving their performance and adapting themselves to changes in the environment. Once trained, the neural network is able to identify the similarities when presented with a new input pattern, resulting in a predicted output pattern. They are able to deal with incomplete information or noisy data and can be very effective, especially in situations where the relationships between inputs and outputs are not sufficiently known. So, ANNs can be ideal alternatives for modeling labor productivity.

II. LITERATURE REVIEW

Ahmed H. El-Batreek, Ahmed S. Ezeldin, Mohamed M. G. Elbarkouky [1] identified top 9 factors that affect labor productivity in Egypt in which availability of material, Respect for craft workers and foremen, availability of health and safety training, Availability of power tools, Availability of drawing, Absenteeism, jobsite orientation program. Awad S. Hanna, Chul-Ki Chang, Kenneth T. Sullivan,

Jeffery A. Lackney [2] identified shift work impact, over manning, extra work affect labor productivity. Abdulaziz M. Jarkas[4] identified top 4 factors that affect labor productivity in concreting in which Concrete workability, Reinforcing steel congestion, Volume of pours, and Height relative to ground level.

B.Prakash Rao , Ambika Sreenivasan,Prasad Babu NV[5] define different method to analyzing the different factor affecting labor productivity Reliability test, Factor analysis, Correlation analysis, Regression Analysis, Descriptive statistics. Gholamreza Heravi, and Ehsan Eslamdoost[7] identified top 18 main factor and sub-factor that affect labor productivity in Iran in which supervision, Proper coordination, Effective communication, Proper planning, Proper HSE program, Technical excellence, Suitable site layout, Labor competence, Sufficient facilities and accommodation, Motivation of labor, Poor decision making, Schedule compression, Frequent change order, Materials, tools and equipment deficiency, Unfavorable external condition after that they apply artificial neural networks for measuring and predicting labor productivity and create the model.

Henry Mwanaki Alinaitwe, Jackson A. Mwakali, Bengt Hansson[8] identified top 36 factor labor productivity in Uganda in which they found all that factor with respect to Time, Cost and Quality. In which Poor construction method, lack of tools and equipment.

III. RESEARCH METHODOLOGY

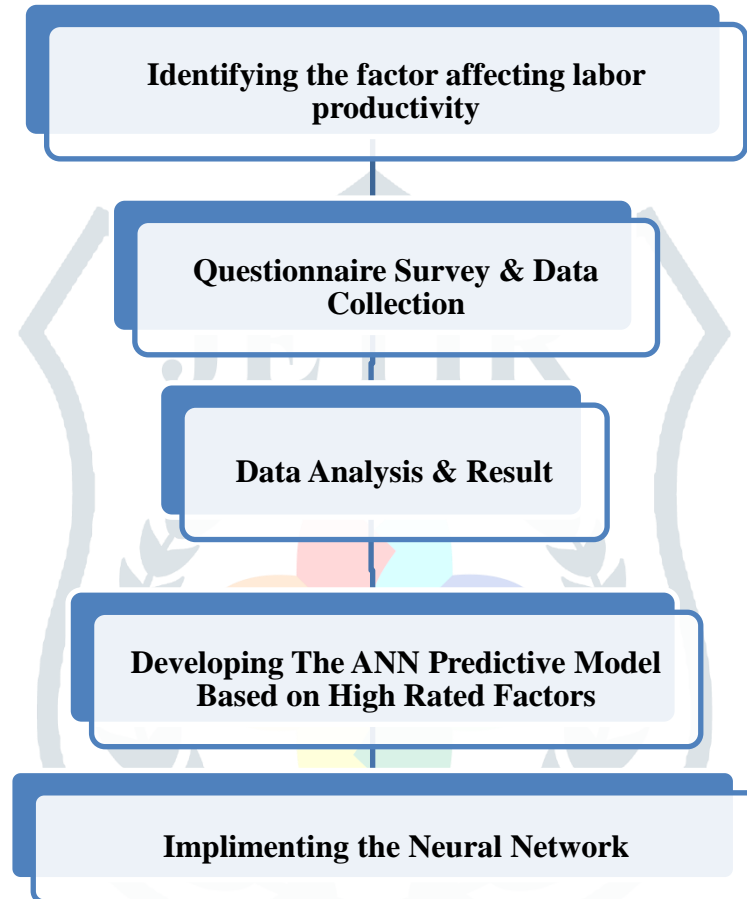


Figure 1 Research Methodology

1. Identifying the factor affecting labor productivity

Identification of factors that influence labor productivity is required to develop the proposed model. So identify the major factors that affect the productivity of labors, different literature have been studied and site visit carried out to identify factor affect labor productivity. Base on this, all 47 identified factor were classified into 8 main factors which is 1) Management 2) Supervision 3) Safety program & motivation 4) Technical Excellence & Site layout 5) Proper planning & scheduling 6) Labor competence 7) Effective communication & language understanding 8) External condition.

Questionnaire Formulation

The questionnaire has five part

- I. Project title and personal information of surveyor
- II. Short description of labor productivity and respondent's detail
- III. Sample of filled questionnaire
- IV. Main questions with 1-5 ratings and Output
- V. Suggestion section for respondent

Pilot Study and Validation

The pilot study was carried out to ensure the validity of the questionnaire. In this study questionnaire given to experts who have 20+ year experience. For review the questionnaire and after that done some changes as per their suggestion.

2. Questionnaire Survey & Data Collection

All the data were collected by the questionnaire survey. The questionnaire was prepared and distributed to 250 Engineers, Consultants, Architects and Contractors in all. Out of which 193 responses were obtained.

Table 1 Brief Summary of Respondents Characteristic

General Information	Frequency	Percentage
JOB TITLE		
Engineer	78	40 %
Consultant	47	25 %
Architect	29	15 %
Contractor	39	20 %
Total	193	100 %
WORK EXPERIENCE		
Under 5 Years	56	29 %
5 – 10 Year	47	24%
10 – 15 Year	40	21%
15 – 20 Year	28	15%
Over 20 Year	22	11%
Total	193	100

3. Data Analysis and Result

The received data were analyzed using the SPSS Software. From that, frequency and Mean were obtained.

Table 2 Top 11 factor Affect Labor Productivity

Main Factor	Sub Factor	Mean
Supervision	Inadequate instruction provided	3.9378
Safety Program & Motivation	Variance in salary for the same job on a project	3.8238
Technical Excellence & site Layout	Material storage area too far from workface	3.8238
Technical Excellence & site Layout	Jobsite congestion	3.8031
Proper Planning & Scheduling	Factors such as change of design, plans, scheduling, and sequence of works	3.7927
Management	Poor decision making	3.6995
External Condition	Bad weather conditions (e.g., high/low temperature, rain, and snow)	3.6943
Effective Communication	Communication with foreign labor	3.6528
Labor Competence	High rate of labor turnover	3.3782
Management	Pulling people off a task before it is done	3.3161
Labor Competence	Labor absenteeism	3.1969

4. Developing ANN Predictive Model Base on High Rated Factor

The network used in this study are multilayer feedforward neural network.

Multilayer Feedforward Architecture

The multilayer feedforward neural network consist of computational neurons that are ordered into distinct output and hidden layers. The connection between two neurons is characterized by the connection weight. Each node involves in an activation (transfer) function that is the rule for mapping the neuron’s summed input to its output. Bias is another neuron parameter that is summed with the neuron’s weighted inputs. For a better illustration, the architecture of a two-layer feedforward network with a single output is shown in Figure.

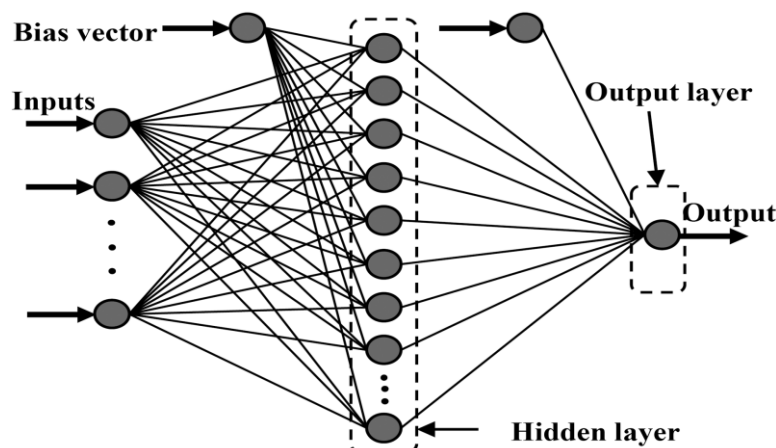


Figure 2 Architecture of two layer neural network (Reference No. [07])

Data Collection and Analysis for artificial neural Network

As an input data, top 11 factors' data were taken from the 90 respondent's questionnaire out of 193 that had experience of more than 10 years. And As an output data, the respondent estimates the approximate labor productivity rate of the purposed project on the basis of data sets such as progress information and labor expenditures, and his/her personal judgment and experience.

$$Labor\ productivity\ (\%) = \frac{Earned\ Work\ Hours}{Expended\ Work\ Hours} \tag{1}$$

Where;

Earned work hours reveals the time duration over which the labor have worked with high efficiency;

and Expended work hour is the total duration over which the labour have worked.

The definition is well adopted for productivity matching with subjective assessment and work experienced assessment of labor productivity and confirms to every activity smoothly.

Model Development

The neural network toolbox of the MATLAB software is utilized to create, train, validate, and test the networks. Total 6 model and different types of network were generated for getting a best result. Ten input neuron has been used. One hidden layer used with three hidden neurons. Number of epochs used are 1000. Learning algorithm used is Levenberg-Marquardt back propagation. Percentage error and Mean Square Error (MSE) have been found. For data normalization neural network inputs typically range from 0 to 1 (inclusive) and usually the output ranges from 0 to 1. Hence, the input and output vector values are converted in the range of 0 to 1.

5. Best Model for Labor Productivity Prediction

After developing the best Labor Productivity prediction Models using ANN with six different combinations of training and validation datasets separately, the comparison is carried out to conclude the final best ANN model among all developed models.

Table 3 Different Prediction Model for Predict labor productivity

ANN Model	Network	Training		Validation	
		RMSE	r	RMSE	r
1	FFDTD	0.093537	0.234981	0.081914	0.263795
2	FFDTD	0.076112	0.594186	0.064254	0.551661
3	LR	0.074013	0.571346	0.068774	0.465581
4	FFDTD	0.075299	0.529739	0.073472	0.313558
5	FFB	0.070771	0.617797	0.075993	0.219141
6	FFDTD	0.083343	0.301545	0.08269	0.031878

From the above Table 5.1 shows that the ANN Models - 6 with Feed Forward Distributed Time Delay training algorithm having RMSE and r value of 0.083343 and 0.301545 respectively during training and RMSE and r value of 0.08269 and 0.031878 during Validation. Hence ANN Model-6 is the best model for Labor Productivity Prediction. The scope of the model is to work within 85% as output data.

6. Implementing the neural network

To demonstrate the prediction performance of the network the developed model are implemented at four real commercial and residential construction project in surat.

- I. It is a commercial project located at Udhana Darwaja, Surat. Having project cost 240 Cr., project duration- 4 years, project status 60% completed, they haven't considered productivity during planning stage.
- II. It is a commercial project located at Piplod, Surat. Having project cost 440 Cr., project duration- 4 years, project status 60% completed, they considered productivity during planning stage.
- III. It is a commercial project located at Katargam, Surat. Having project cost 30 Cr., project duration- 4 years, project status 20% completed, they considered productivity during planning stage.
- IV. It is a commercial project located at Vesu, Surat. Having project cost 160 Cr., project duration- 30 months, project status 60% completed, they haven't considered productivity during planning stage.

Table 4 Detail of Case Study

Project	Duration (Years)	Cost of the Project (Cr.)	Expected Productivity	Predicted Productivity
I	4	240	80	77
II	4	440	70	73
III	4	30	85	65
IV	2.5	160	80	74

IV. CONCLUSION

From the literature review and interviews with the expert panel, 47 factors were finalized that affects the labor productivity within the scope of work and distributed in eight main categories as: Management, Supervision, Safety program and motivation, Technical excellence and site layout, Proper planning and schedule, Labor competence, Effective communication and language understanding, and External condition.

For evaluating and distinguishing the crucial factors influencing the labor productivity data collection was done by questionnaire survey where total 193 response were received by the engineers, consultants, architects and contractors altogether and analyzed by the mean variance analysis using SPSS tool to obtain the top 11 factors that affects labor productivity to the greater extent as enlisted below:

1. Inadequate instruction provided.
2. Variance in salary for the same job on a project
3. Material storage area too far from workplace.
4. Jobsite congestion.
5. Factors such as change of design, plans, scheduling, and sequence of works.
6. Poor decision making.
7. Bad weather conditions (e.g., high/low temperature, rain, and snow).
8. Communication with foreign labor.
9. High rate of labor turnover.
10. Pulling people off a task before it is done.
11. Labor absenteeism.

MATLAB software was used to generate an ANN model to predict the productivity. In total, six models were generated by the different ANN network and training-testing percentage.

- ❖ 1st model is 60% to 40%.

In this model, 11 network were generated. In this model, we found FFDTD as the best model.

- ❖ 2nd model is 65% to 35%.

In this model, 3 network were generated. In this model, we found FFDTD as the best model.

- ❖ 3rd model is 70% to 30%.

In this model, 11 network were generated. In this model, we found LR as the best model.

- ❖ 4th model is 72% to 28%.

In this model, 3 network were generated. In this model, we found FFDTD as the best model.

- ❖ 5th model is 80% to 20%.

In this model, 11 network were generated. In this model, we found FFB as the best model.

- ❖ 6th model is 85% to 15%.

In this model, 3 network were generated. In this model, we found FFDTD as the best model.

- Amongst all the six models, it was found out that 85% -15% FFDTD is the best model.

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