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Estimation of Production rates for Formwork Installation using Fuzzy Expert Systems

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ESTIMATION OF PRODUCTION RATES FOR FORMWORK INSTALLATION USING FUZZY EXPERT SYSTEMS

Strictly as per the compliance and regulations of:

Estimation of Production rates for Formwork Installation using Fuzzy Expert Systems

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Abstract - Expert Systems have been used to solve complex problems efficiently if the information available is in descriptive form rather than numbers. The study has aimed to use Fuzzy expert systems to estimate the labor production rates. Production rate values of formwork installation of beam have been measured from the project sites and factors influencing the production rates have been recorded on scale in descriptive form. Fuzzy expert system developed in this study has been compared with the previous Fuzzy expert systems used for estimating production rates. Mean Square Error of the previous and new models has been calculated and shows that proposed model gives high linguistic and numerical accuracies. Hence, the Fuzzy expert system developed in this study can be used reliably for estimating labor productivity by the construction Industry.

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I. Introduction

Construction productivity is the main indicator of the performance of construction industry. It is constantly declining over a decade due to the lack of standard productivity measurement system and negligence of various factors influencing labor productivity. Different techniques have been developed to estimate construction productivity. These includes Factor Model by Thomas and Yiakoumis (1987) for predicting productivity using factors, Expectancy model by Maloney and Fillen (1985) for predicting performance of workers to estimate productivity, Action Response model by Halligan (1994) to evaluate losses in construction productivity, Herbsman and Ellis (1990) have developed Statistical model to identify the affects of factors on productivity, An Expert Simulation model developed by Boussaabaine and Duff (1996) to identify the combine effects of the factors on productivity. These modelling techniques have been developed for specific conditions and their implementation was mostly restricted with the information available (Oduba 2002). In addition, in order to solve complex non-linear problems these techniques have several limitations.

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Therefore, the objective of this study is to use Artificial Intelligence technique for the estimation of labor productivity. It has been identified that Artificial Intelligence techniques have been using to solve the problems in construction management research through decades. These techniques have strong and dynamic learning mechanism with effective recognition capabilities to solve complex non-linear problems. Among the different Artificial Intelligence techniques the most commonly used in construction management is Fuzzy Expert System.

II. Fuzzy Expert System

Fuzzy expert systems relates input variable with output variables in the form of linguistic values based on fuzzy if-then rules. Membership functions of input variables represented by fuzzy antecedents of if-then rules whereas the membership functions of the output variables represents fuzzy consequents of if-then rules (Aminah *et al.* 2005). Reasoning of fuzzy expert systems is based on fuzzy inference mechanisms. The basic structure of fuzzy inference mechanism consists of three components: *rule base*; which contain selection of rules, *database*; which defines membership function used in fuzzy rules and *reasoning mechanism*; which perform inference procedure (Jang *et al.* 1997).

There are few applications of fuzzy expert systems in the field of construction management. For estimating construction labor production rates, fuzzy expert system has been used by Hongwei (1999) and Oduba (2002). Hongwei (1999) has estimated labour productivity using fuzzy set theory. Method of using fuzzy set theory has been explored for estimating labor production rate for concrete wall formwork. Different factors influencing labor productivity of concrete wall formwork have been identified and fuzzy logic estimation model has been developed. Fuzzy inference engine, fuzzification module and defuzzification module have been prepared and productivity has been predicted as a linguistic assertion. However, the data used in this research are based on historical records which are limited and inconsistent therefore the accuracy of the results of fuzzy expert system developed can be questioned.

Oduba (2002) has also predicted labor productivity using fuzzy expert systems. Productivities for industrial rig pipe and weld pipe activities has been predicted after identifying the various influencing factors on these activities. To identify the influence of these factors membership functions have been developed. Relationship between the productivities with influencing factors has been predicted by developing fuzzy rule-base in fuzzy expert systems. Despite the fuzzy expert systems resulted in high linguistic accuracy but the use of large number of input factors has caused exponential growth of rules and made it complicated to understand.

Therefore, this study has aimed to use fuzzy expert system for estimating construction labor production rates by collecting the data from direct observation of project sites and develop fuzzy expert system by using selected factors that significantly influence the productivity of labor.

III. Factors Influencing Labor Productivity

Through the literature review, total seventeen factors that influenced the labor production rates at site have been identified.

Table 1 : Importance Index Parameters

Influencing Factors	Importance Index	Ranking
Availability of material & equipment	66	**1**
No. of workers	61	**2**
Weather	60	**3**
Site Conditions	59	**4**
Location of the project	58	**5**
Motivation and incentive	54	6
Labor work load	51	7
Absenteeism	40	8
Rework	37	9
Delays in material delivery to site	36	10
Inspection delays	35	11
Labor disruption	33	12
Poor Scheduling and Coordination	32	13
Disruption of Power/Water Supplies	30	14
Communication Problems	31	15
Skill level of labor	29	16
Buildability	28	17

Table 2 : Influencing factors Parameters

Factors/ Likert Scale	1	2	3	4	5
	Low Severe	**Slightly low Severe**	**Moderate**	**Slightly high severe**	**Highly severe**
Weather (F1)	Very Pleasant	Pleasant	Moderate/sunny	Hot weather	Very hot weather
Availability of material and Equipment (F2)	Completely available	Adequately available	Inadequately available	Shortage of material	Completely unavailable
Location of project (F3)	Accessible/Urban area	Sub-urban area	Rural-urban	Sub-rural area	Inaccessible/ Rural area
Site conditions (F4)	Very clear	clear	Slightly congested	congested	Very congested
Number of workers (F5)	Completely available	Adequately available	Inadequate Availability	Shortage of workers	Completely unavailable

Questionnaire survey has been carried out to rank each factor according to their importance by using Likert scale of 1 to 5 where 1 means not important and 5 means extremely important. Factors are ranked as highly significant by calculating the Importance Index by using the formula;

$$\text{Importance Index} = \frac{5n_1 + 4n_2 + 3n_3 + 2n_4 + n_5}{5(n_{1+}n_2 + n_3 + n_4 + n_5)}$$

Top five factors have been selected which are weather, availability of material and equipment, project location, site conditions and number of workers as shown in Table 1. These factors have been selected to record at sites on the Likert scale of 1 to 5 where 1 means low severe and 5 means high severe as shown in Table 2.

IV. Production Rates

Various ongoing concrete building projects have been identified in different parts of Malaysia that includes Ipoh, Kuala Lumpur, Grik, Subang, Selangor, Melaka. Direct observation method has been used to measure the production rates and influencing factors at site. Production rates of installation of formwork of beam have been selected to measure. Simultaneously, five factors selected earlier have also been recorded. Total seven numbers of projects have been observed. Weekly site visits had been done and are the production rates are recorded at specific interval of times. Eighty four (84) numbers of observations have been collected. Stop watch has been used to calculate duration of activities at specific time interval.

V. Model Development

Fuzzy expert systems developed previously for predicting labor productivity have been considered. Two fuzzy logic models that have been developed by Hongwei (1999) and Oduba (2002) for estimating labor productivity. New Fuzzy expert system has also been developed by considering new parameters.

a) Model 1(Hongwei 1999)

Same parameters of fuzzy expert system have been considered as developed by Hongwei in 1999. For input variables and output variable three membership functions have been used with five linguistic terms. The shape of the membership function used for input variable and output variable is triangular. Fuzzy if-then rules have been developed through logical reasoning. Mamdani inference system has been considered with min-max composition where implication and aggregation methods used are minimum and maximum. Mean of Maximum (MOM) method is used for defuzzifucation.

b) Model 2 (Oduba 2002)

Similarly the parameters of the fuzzy expert system developed by Oduba in 2002 have been considered. Three membership functions have been used for input and output variables with three linguistic terms. The shape of the membership function used for input variable and output variable is triangular. Fuzzy if-then rules have been developed through logical reasoning. Mamdani inference system has been considered with min-max composition and implication and aggregation methods used are minimum and maximum. Defuzzification method used is centriod.

c) New Model

A new fuzzy expert system has been developed with new parameters. Five membership functions have been used for input and output variables with five linguistic terms. The shape of the membership function used for input variable and output variable is gaussian. Fuzzy if-then rules have been developed through logical reasoning. Sugeno inference system has been considered with min-max composition where implication and aggregation methods used are minimum and maximum. Defuzzification method used is weight age average.

VI. Performance of Models

Data collected in this research have been used in the two previously developed and newly developed Fuzzy Expert systems. Performance of the systems has been evaluated by calculating Mean Square Error (MSE), numerical and linguistic accuracies.

As shown in Table 3, MSE calculated from New Model is lower than Model 1 and Model 2. Thus, indicating that New Model has estimated the production rates with least range of errors.

Numerical accuracies for Model 1 and Model 2 have been calculated. Percentage error of each data points have been measured and the numerical match is considered if error is less than 33% as three membership functions have been used representing 33% of the data. Numerical accuracy is obtained by calculating percentage of numerical matches over total number of data points (Oduba 2002). Similarly, if the defuzzified output matches with the linguistic term of actual output then it is considered linguistic match. Numerical accuracies calculated for Model 1 and Model 2 are equal to 44% and 71%. Model 2 resulted in high numerical accuracy as compare to Model 1. The linguistic accuracies of Model 1 and Model 2 are 21% and 50% which are significantly lower.

Table 3 : Fuzzy Expert Systems Results

Fuzzy Expert Systems	**Formwork installation of Beam**		
	MSE	**Numerical Accuracy**	**Linguistic Accuracy**
MODEL 1	0.000390	44%	21%
MODEL 2	0.1645	71%	50%
NEW MODEL	0.000067	75%	53%

For New Model, numerical accuracies have been calculated. However, percentage error less than 20% is considered as numerical match as the five linguistic terms have been used where each membership function representing 20% of data. Table 3 shows that the numerical and linguistic accuracies calculated from New Model is 75% and 53% which are higher as compare to Model 1 and Model 2. Thus for this study, changing the shape of membership function from triangular to Gaussian, linguistic terms from three to five, fuzzy inference system from Mamdani to Sugeno and Defuzzification method from centriod and Mean of Maximum to weight age average; gives more reliable and accurate results with high numerical and linguistic accuracies.

VII. Conclusion and Recommendations

Construction labor production rates of formwork installation of beams have been estimated by using influencing factors which were in descriptive forms. This study has achieved its objective by estimating reliable production rates for formwork installation by using Fuzzy Expert System with least Mean Square Error and with high numerical and linguistic accuracies. However, for more accurate results the study can be conducted by increasing more data. Also, sensitivity analysis is needed to identify the influence of each factor on the production rates.

Hence, this study has provided a framework for developing more accurate estimation technique using fuzzy expert system in the field of construction management.

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