IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 08, Issue 3 (March. 2018), ||V1|| PP 34-40

Equipment Productivity Forecasting Model for Multi-storey Building Construction Through Regression Analysis

[1]Neelima Suresh J, [2]Sahimol Eldhose
M.Tech Student, Toc H institute of Science and Technology, Ernakulam
Assistant Professor, TIST, Ernakulam
Corresponding author: Neelima Suresh J

Abstract: *Construction productivity measurement is the analysis into the ratio of total output to the total input of the construction process. Inputs generally refer to labor, equipment and materials cost and output in terms of total value of the project. The aim of this study is to identify critical factors that affects equipment productivity and to develop a mathematical model for equipment productivity forecasting of building construction and to do the validation of the model. Identification of factors is done by conducting literature survey and interview session with the site engineers,project engineers and contractors and are evaluated using relative importance index method. Based on the identified factors equipment productivity forecasting model is developed using Multivariate Linear Regression Technique(MLR).The model was developed using 50 sets of data collected from multi-storied residential projects in Trivandrum. It is found that MLR have the ability to forecast the productivity with good degree of accuracy of the coefficient of correlation(R) 73% for Equipment productivity model.*

Date of Submission: 17-02-2018 Date of acceptance: 03-03-2018

I. INTRODUCTION

Productivity is one of the key components of every company's success and competancy in the market.The output and inputs of production thus constitute the basic components of every productivity measure. Productivity measures are formulated as a ratio of output to one or more of the inputs. Previous studies regarding productivity indicate that a broad range of factors affect productivity.In order to improve productivity, a study of the factors affecting it whether positevely or negatively is necessary. Previous studies regarding productivity indicate that a broad range of factors affect productivity. The factors that influence productivity may be mainly separated into three factors: labor-related, material-related, and equipment-related factors. Making use of these factors that positively affect productivity and controlling factors that have a negative effect, will ultimately improve the productivity. This study addresses material related factors.Construction companies may gain advantage over their competitors by improving upon productivity to build projects at lower costs; yet, most contractors do not systematically and properly address this strategic issue or evaluate its impact on the project's profit. Productivity measurement at construction site level enables companies to monitor their own performance against their site performance.

II. RESEARCH OBJECTIVE

The main objectives of this study are evolved through the literature survey and are listed below.

- To identify critical factors affecting equipment productivity of multi-storey buildings
- To propose a mathematical model for forecasting equipment productivity of multi-storied buildings.
- To define the degree of accuracy of the mathematical model

III. RESEARCH METHODOLOGY

1. Literature survey: The identification of research problem and the collection of information required for the progress of work are done through the literature survey.Factors affecting equipment productivity is identified.
2. Data Collection: The relevant data to identify critical factors were collected by a structured, closed-ended questionnaire survey.Datas regarding equipment productivity are collected by field study.
3. Data Analysis:Relative Importance Index(RII) method is used to rank the factors.SPSS was used for determining the productivity rate characteristics. Various statistical analysis methods including descriptive statistics,correlation.
4. Model Generation : Mathematical model is generated for forecasting equipment productivity using multiple regression technique.Based on the data analysis results, multiple linear regression models for predicting construction equipment productivity is generated.

6. Validation of The Model: Model is validated using another set of datas.
7. Discussion And Conclusion: Based on the analysis of results and model generated, conclusion and future study were discussed.

IV. PREVIOUS STUDIES ON PRODUCTIVITY

Abdulaziz M. Jarkas, and Camille G. Bitar (2012) [1]identified and ranked the relative importance of factors that affected labor productivity on construction sites in Kuwait.The clarity of technical specifications factor ranks first among the 45 factors explored, and thus considered the most significant factor affecting construction labor productivity in Kuwait with a relative importance index of 81.67%. Argaw Tarekegn Gurmu and Ajibade Ayodeji Aibinu (2017)[3] identified construction equipment management practices that have the potential to improve productivity in multi-storey building projects.Data were collected from 39 principal contractorson 39 projects using questionnaires. Construction equipment maintenance, construction equipment procurement plans, and construction equipment productivity analysis are identified as the three construction equipment management practices that could improve productivity in multi-storey building projects.

Argaw Tarekegn Gurmu and Ajibade Ayodeji Aibinu (2017)[3] identified construction equipment management practices that have the potential to improve productivity in multi-storey building projects. This study used an exploratory sequential mixed-methods research design involving a combination of qualitative and quantitative data in two phases. The qualitative phase may be used to build an instrument that best fits the sample under study, identify appropriate instruments to use in the follow up quantitative phase, or specify variables that need to go into a follow-up quantitative study. Data were collected from 39 principal contractors on 39 projects using questionnaires The quantitative data were analyzed to prioritize the practices identified in Phase I, and on that basis, a scoring tool for measuring the practices was developed; a logistic regression model was also developed for predicting the probability of exceeding baseline productivity factor using a sigmoid graph when the score of the practices is known. Construction equipment maintenance, construction equipment procurement plans, and construction equipment productivity analysis are identified as the three construction equipment management practices that could improve productivity in multi-storey building projects.

Bon-Gang Hwang et al. (2017)[5]identified the critical factors affecting the productivity of green building construction projects.The results indicated that experience of the worker, technology, changes in design, skill of worker, and planning and sequencing of work were the top five most critical factors that affect the productivity of green building construction projects.Gholamreza Heravi and Ehsan Eslamdoost (2015)[7] developed a labor productivity model based on multilayer feed forward neural networks trained with a back propagation algorithm by which complex mapping of factors to labor productivity is performed. This paper focused on the work involved in installing the concrete foundations of gas, steam, and combined cycle power plant construction projects in the developing country of Iran. The results proved a better prediction performance for Bayesian regularization than early stopping. To demonstrate the prediction performance of the presented models, the developed models are implemented at two real power plant construction projects.

Govindan Kannan (2014)[8] evaluated the performance of the tools and to record observations. The paper focused on repair costs, residual value and total cost and productivity, typically referred to as total cost of ownership. The paper don't cover any aspects of the future designs of machines nor explore the trends of the construction equipment market. All of the concepts and tools developed around this research were found to be well accepted in the construction industry. Resale Value Model was developed. The model on resale value considers manufacturer, auction year, year of manufacture, and auction price. The probability (likelihood) of failure approach uses an instance of life on the basis of predefined parameters. This approach requires the simulation of multiple instances with different component lives on the basis of a predefined distribution.

Khaled, Mahmoud El-Gohary and Remon, Fayek Aziz (2013)[12]identified, investigated, and ranked factors perceived to affect construction labor productivity in the Egyptian construction. The survey presents 30 productivity factors generated on the basis of related research works on construction productivity.The most important factors identified are labor experience and skills, incentive programs, availability of the material and ease of handling, leadership and competency of construction management and competency of labor supervision.

Rodrigo.A.Rivas et al.(2011)[14] focused on identifying and understanding the productivity factors affecting projects in a Chilean construction company. The main findings indicate that the critical areas affecting construction productivity were related to materials, tools, rework, equipment, truck availability, and the workers' motivational dynamics. The data for this study were the results of 28 questionnaires administered to 19 direct workers (foremen, craftsmen, and helpers) and nine mid-level employees (administrative, warehouse, quality control, and field supervisors) working on the projects. Serdar Durdyev et al. (2014)[14] identified systematically the factors that can often affect productivity and perceived service quality directly or indirectly.The results also show that most of the factors influencing productivity and PSQ in Turkey are originated from lack of skilled and experienced workforce, proper work and quality management. Because of the labour-intensive nature of the HIS, skill and experience of the labour is very significant to achieve both high productivity and PSQ, as skill and experience improves labour in different ways such as intellectual and physical abilities, which are directly affecting both overall productivity and PSQ.

Wen Yi1 and Albert P.C. Chan (2013)[16] presented a systematic review on labor productivity in the construction industry. The aim of this review was to investigate the state of the art and trends in CLP research, and to identify key research areas. To acquire a more elaborated understanding of CLP research, it carried out a three-stage literature review to conduct a content analysis of CLP papers from 1983 to 2011. A total of 135 CLP-related papers were identified from the selected journals.Six major areas on CLP research interests have been identified through a detailed review and analysis on the selected 113 papers, including factors affecting CLP; CLP modelling and evaluation; method and technology for CLP improvement; CLP trends and comparisons; effect of change/variation on CLP; and baseline/ benchmarking CLP.

V. IDENTIFICATION OF FACTORS AFFECTING EQUIPMENT PRODUCTIVITY

In order to generate model for productivity prediction, factors affecting productivity has to be first identified. The methodology used in this research to determine the factors affecting the construction productivity involves; Literature survey and Preliminary interviews.A number of personal interviews were conducted with engineers who work as a project manager, estimators, planners and site engineers.Relying on personal interviews and the literature review, factors affecting the equipment productivity was identified.Relative Importance Index method was used to rank the factors.

$$RII = \frac{5(n5)+4(n4)+3(n3)+2(n2)+n1}{5(n1+n2+n3+n4+n5)} x100 \quad (1)$$

where n1, n2, n3, n4, and n5 = the number of respondents who have selected: 1, for no effect; 2, for little effect; 3, for moderate effect;4, for strong effect; and 5, for very strong effect, respectively.

VI. IDENTIFICATION OF EQUIPMENT PRODUCTIVITY MODEL VARIABLES

Seven independent variables were carefully selected. Factors having relative importance value above 50 were selected from each of the three categories.

Table 1: Independent Variables

Factors	Variables
Regular maintenance of equipment	X_1
Specification ofequipment	X_2
Working cycle	X_3
Fund shortage to procure	X_4
Handling of equipment	X_5
Age of Equipment	X_6

VII.DEVELOPMENT OF REGRESSION MODEL FOR EQUIPMENT PRODUCTIVITY

The SPSS software is used to develop the model.SPSS statistical tool is used to perform regression analysis,following the steps:

Step1: Input Data

Figure 1 shows all the dependent and independent variables selected.These independent variables can be classified into two type, objective and subjective variable.For subjective variables dummy coding is done.

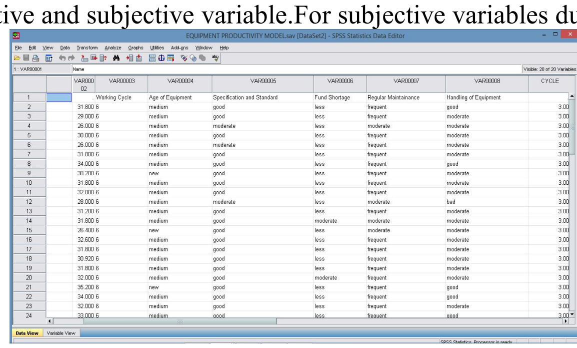


Figure 1. Input Data

Step2 : Choose Regression Analysis

Figure 2 shows the selection of regression analysis.From the menu bar choose analyse and then select regression and then choose linear.

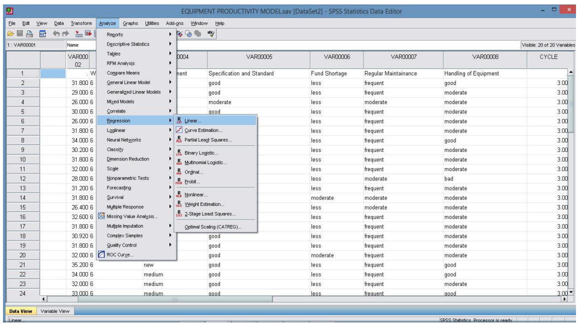


Figure 2.Regression Analysis

Step:3 Select the Dependent and Independent Variables as in figure 3.

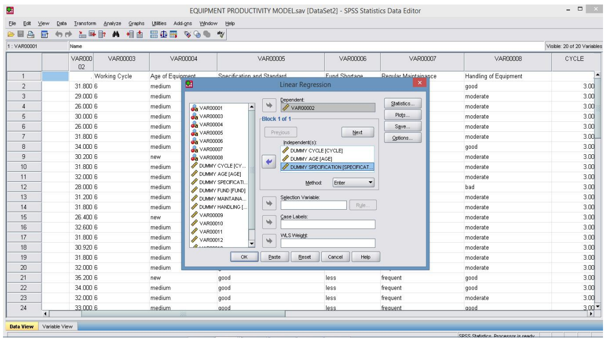


Figure 3. Variable Selection

Step4 : Choose statistics and then select model fit,R squared change, descriptives, part and partial correlations and click continue as shown in figure 4.

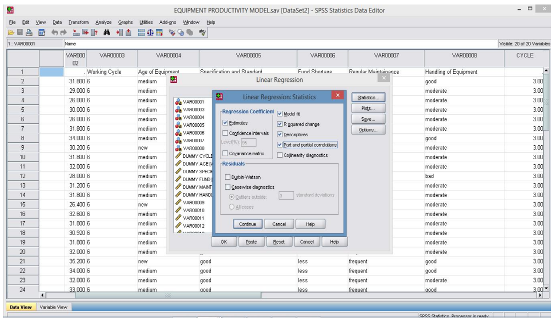


Figure 4. Statistics Selection

Step5 : Choose enter method and click ok.

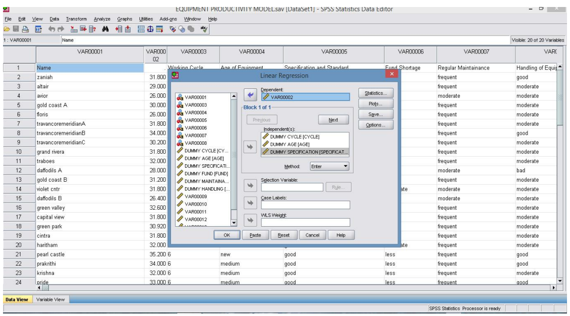


Figure 5.Enter Method

Step6 : Result

The final result of regression analysis is obtained.Table2 shows the means and standard deviation of the variables.

Table 2. Descriptive Statistics

	Mean	Std. Deviation	N
EQUIPMENT PRODUCTIVITY	31.11080	2.773131	50
DUMMY CYCLE	2.8800	.32826	50
DUMMY AGE	2.8200	.38809	50
DUMMY SPECIFICATION	2.8200	.38809	50
DUMMY FUND	2.9600	.19795	50
DUMMY MAINTAINANCE	2.8400	.37033	50
DUMMY HANDLING	2.6000	.67006	50

Table 3 shows that the correlation coefficient and the sigma value is less than 0.05 so it is good. Results of coefficient of correlation and (coefficient of determination) showsthat there is a good correlation between equipment productivity and other Input variables. This indicates the acceptance relationship of between dependent and independent variables.

Table3. Model Summary

Mode	R	R Square	Adjusted R Square	Sig. F Change
1	.730	.533	.467	.000

The table 4 shows the beta coefficients and Unstandardized Coefficients for the regression.This model includes all the potential independent variables that have been identified.

Table 4. Unstandardized Coefficients of Variables

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	15.066	6.169		2.442	.019
	DUMMY CYCLE	.514	.912	.061	.564	.576
	DUMMY AGE	.017	.808	.002	.022	.983
	DUMMY SPECIFICATION	4.644	.907	.650	5.122	.000
	DUMMY FUND	-1.009	1.537	-.072	-.656	.515
	DUMMY MAINTAINANCE	2.263	.918	.302	2.464	.018
	DUMMY HANDLING	-.777	.526	-.188	-1.478	.147

From Table 4, the regression equation is obtained as:

$$Y=15.066+0.514X_1+0.017X_2+4.644X_3-1.009X_4+2.263X_5-0.777X_6 \quad (2)$$

VIII. VALIDATION OF MODEL

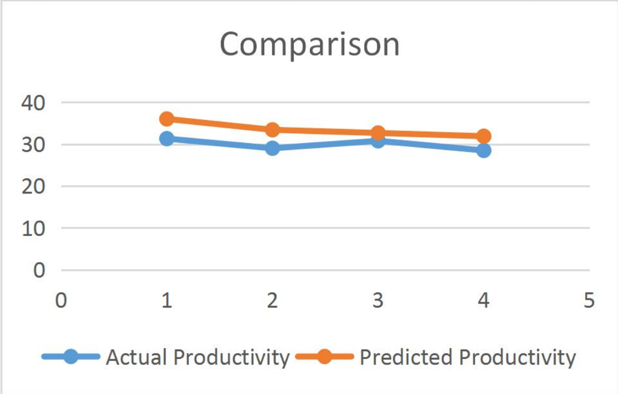
In this research, new data is collected to check the model and its predictive ability. Five new observations for each concerning variables were collected. These observations are not included in the model calibration procedures and were used as independent verification check.The actual productivity and the predicted values are presented in Table 6.

Table 6. The actual and the predicted productivity

Project	Actual productivity	Predicted productivity	|A-P|/A
P1	31	36	0.15057
P2	29	33.4	0.15172
P3	30	32.65	0.06089
P4	28	31.87	0.11903

The analyzed results indicates that the material productivity by suggested productivity estimation function are closer to the actual productivity.

Figure 6.Comparison of predicted and actual productivity



IX. ACCURACY OF THE DEVELOPED REGRESSION MODEL

The statistical measures used to measure the performance of the models included [41]:

1) Mean Absolute Percentage Error (MAPE),

$$MAPE = \left. \left(\sum_{t=1}^{n} \frac{A-P}{P} * 100 \right) \middle/ n \right.$$

2) Average Accuracy Percentage (AA%)

$$AA\% = 100 - MAPE$$

3)The Coefficient of Determination (R^2)

4)The Coefficient of Correlation

The MAPE and Average Accuracy Percentage generated by MLR model were found to be (2.24%) and (97.76%) respectively. Therefore, it can be concluded that the MLR model show good agreement with the actual measurements.

Table 7. Statistical measures results

Measures	MAPE%	AA%	R	R^2
Results	10.65	89.35	0.730	0.533

X. CONCLUSION

From the results presented in this research, the following conclusions can be made:

1. The main factors affecting construction equipment productivity are identified and ranked.
2. Multivariable Linear Regression (MLR) can be used to examine several variables at once and the inter-relationships between them.
3. Equipment productivity forecasting model has been developed with seven influential factors with coefficient of determination of developed model equal to 0.533.
4. Using linear regression technique gives average accuracy percentage 89.35%and mean absolute percentage error 10.65%.
5. Model helps to achieve a competitive level of quality and cost effectiveness in projects.For future research, the study recommends expanding the use of multivariate regression for commercial buildings as well.

REFERENCES

[1] . Abdulaziz M. Jarkas and Camille G. Bitar (2012) "Factors Affecting Construction Labor Productivity in Kuwait", Journal of Construction Engineering and Management,138,pp.811-820

[2] . Abraham Assefa Tsehayae and Aminah Robinson Fayek (2016) "Developing and Optimizing Context-Specific Fuzzy Inference System-Based Construction Labor Productivity Models",Journal of Construction Engineering and Management,142,pp.704-714

[3] . Argaw Tarekegn Gurmu and Ajibade Ayodeji Aibinu (2017) "Construction Equipment Management Practices for Improving Labor Productivity in Multi-storey Building Construction Projects", Journal of Construction Engineering and Management, 143,pp.810-813

[4] . Arun Makulsawatudom and Margaret Emsley (2014) "Factors Affecting The Productivity Of The Construction Industry In Thailand: The Foremen's Perception", Construction Research Congress, 130,pp.340-363
[5] . Bon-Gang Hwang, Lei Zhu and Jonathan Tan Tzu Ming (2017) "Factors Affecting Productivity in Green Building Construction Projects: The Case of Singapore", Journal of Construction Engineering and Management, 33,pp.352-368
[6] . Chien-Liang Lin and Hong-Ming Huang (2010) "Improved Baseline Productivity Analysis Technique", Journal of Construction Engineering and Management, 136,pp.367-376
[7] . Gholamreza Heravi and Ehsan Eslamdoost (2015) "Applying Artificial Neural Networks for Measuring and Predicting Construction-Labor Productivity", Journal of Construction Engineering and Management, 141,pp.303-313
[8] . Govindan Kannan (2014)" Field Studies in Construction Equipment Economics and Productivity", Journal of Construction Engineering and Management, 137,pp.823-828
[9] . Hemishkumar Patel, Jayeshkumar Pitroda and Prof. J. Bhavsar (2013) Analysis of Factor Affecting Material Management And Inventory Management: Survey of Construction Firms In Gujarat Region Of India, Journal of Construction Engineering and Management,pp.320-346
[10] . Jiukun Dai, Paul M. Goodrum and William F. Maloney (2009) "Construction Craft Workers' Perceptions of the Factors Affecting Their Productivity", Journal of Construction Engineering and Management, 135,pp.217-226
[11] . Joanicjusz Nazarko and Ewa Chodakowska (2015) "Measuring productivity of construction industry in Europe with Data Envelopment Analysis", Procedia Engineering, 122,pp.204 – 212
[12] . Khaled Khaled, Mahmoud El-Gohary and Remon, Fayek Aziz (2013) "Factors Influencing Construction Labor Productivity in Egypt", Journal of Construction Engineering and Management, 30,pp.234-264
[13] . Paul M. Goodrum, Dong Zhai and Mohammed F. Yasin (2009) "Relationship between Changes in Material Technology and Construction Productivity", Journal of Construction Engineering and Management,135,pp.278-287
[14] . Serdar Durdyev, Ali Ihtiyar, Syuhaida Ismail, Fauziah Sh. Ahmad and Nooh Abu Bakar (2014) Productivity and Service Quality: Factors Affecting in Service Industry, Procedia - Social and Behavioral Sciences, 109, 487 – 491
[15] . Tao Wang, Yadong Yu, Wenji Zhou, Bomin Liu, Dingjiang Chen and Bing Zhuet (2015) "Dynamics of material productivity and socioeconomic factors based on auto-regressive distributed lag model in China", Journal of Cleaner Production, 137,52-761
[16] . Wen Yi and Albert P. C. Chan (2014) Critical Review of Labor Productivity Research in Construction Journals, Journal of Management in Engineering, 30, 450-497

IOSR Journal of Engineering (IOSRJEN) is UGC approved Journal with Sl. No. 3240, Journal no. 48995.

Neelima Suresh J "Equipment Productivity Forecasting Model for Multi-storey Building Construction Through Regression Analysis "IOSR Journal of Engineering (IOSRJEN), vol. 08, no. 3, 2018, pp. 34-40.