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Model for Material Productivity Forecasting of Multi-storey Building Construction

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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 material productivity and to develop a mathematical model for material 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 material 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) 82.9% for Material productivity model.*

1. INTRODUCTION

Productivity is one of the key components of every company's success and competancyin 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 positively 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.

2. RESEARCH OBJECTIVE

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

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

3. 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 productivity of a construction site is identified.
2. Data Collection: The relevant data to identify critical factors were collected by a structured, closed-ended questionnaire survey. Datas regarding labor, material and 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 material productivity using multiple regression technique. Based ont he data analys is results, multiple linear regression models for predicting construction 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.

4. 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 contractors on 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 multistory 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.

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)[15] 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.

5. IDENTIFICATION OF FACTORS AFFECTING MATERIAL 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 material 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.

6. MATERIAL-RELATED FACTORS

The relative importance indices and ranks of the 10 factors classified under the material group are shown in Table 1

Table 1: Relative Importance Indices and Ranks of Material Group Productivity Factors

Factors	RII	Rank
Ease of availability of material	81.5	5
Quality checking of material	90.5	2
Cost of the material	80	6
Storage facility	79.5	7
Material Requirement Planning	92.5	1
Periodic inspection	85.5	3
Amount of wastage	82	4
Weather condition	41	10
Loading and unloading of materials	43.5	9
Delay in supply	44	8

7. IDENTIFICATION OF MATERIAL 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 2: Independent Variables

Factors	Variables
Material Requirement Planning	X_1
Periodic inspection	X_2
Cost of the material	X_3
Quality Checking of materials	X_4
Storage facility	X_5
Amount of wastage	X_6
Ease of Availability	X_7

8. DEVELOPMENT OF REGRESSION MODEL FOR MATERIAL 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. The first group (objective variables) comprised variable that are real number and the others are categorical variable that represent on choice of categories. For subjective variables dummy coding is done.

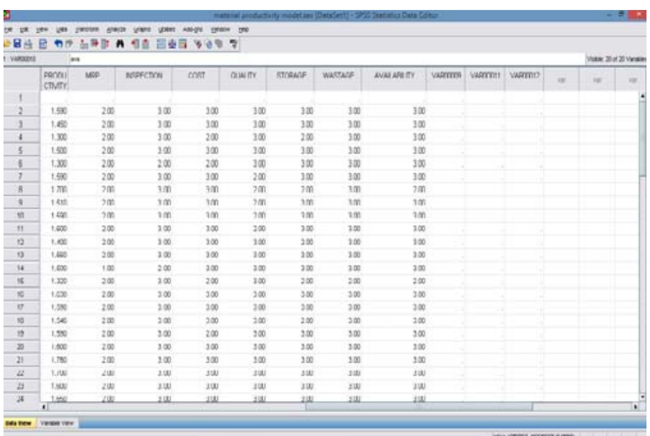

Figure 1: Input Data

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.

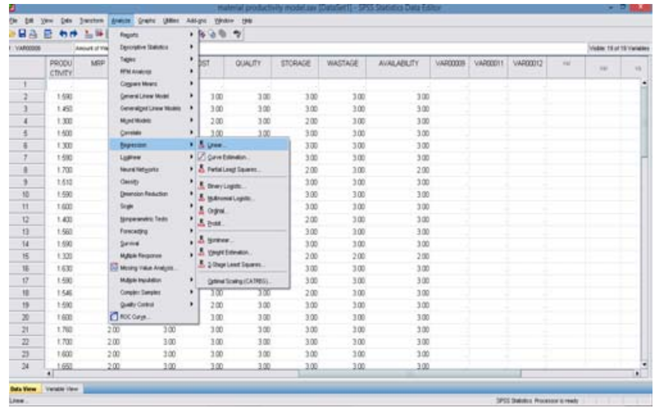

Figure 2: Regression Analysis

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

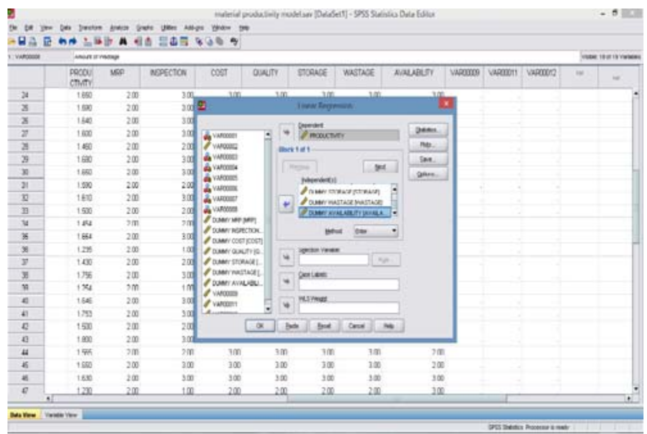

Figure 3: Variable Selection

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

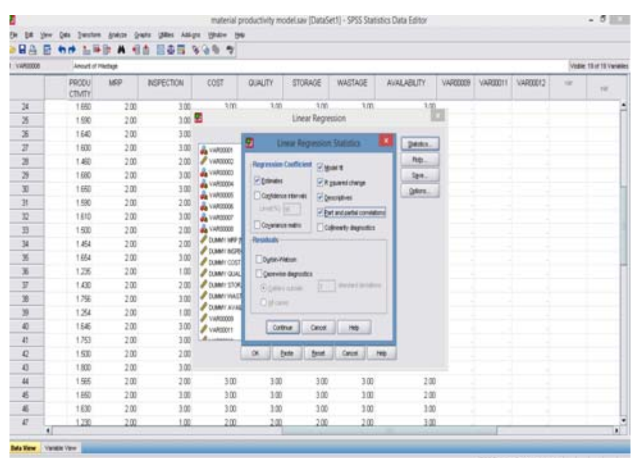

Figure 4. Statistics Selection

Step5 : Choose enter method and click ok.

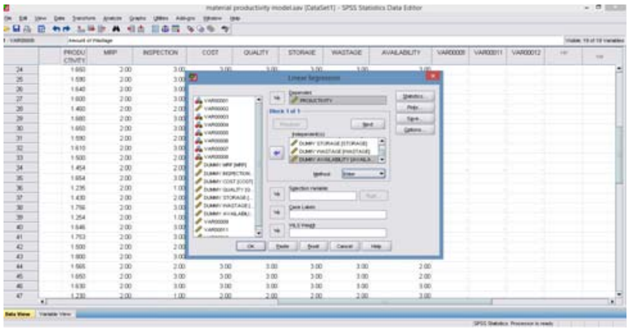

Figure 5: Enter Method

Step6 : Result

The final result of regression analysis is obtained.Table3 shows the means and standard deviation of the variables.

Table 3: Descriptive Statistics

	Mean	Std. Deviation	N
PRODUCTIVITY	1.55554	.138657	50
DUMMY MRP	1.9800	.14142	50
DUMMY INSPECTION	2.6400	.63116	50
DUMMY COST	2.8000	.40406	50
DUMMY QUALITY	2.8000	.40406	50
DUMMY STORAGE	2.7400	.44309	50
DUMMY WASTAGE	2.9200	.27405	50
DUMMY AVAILABILITY	2.8400	.37033	50

Table 4 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 very good correlation between material productivity and other Input variables. This indicates the acceptance relationship of between dependent and independent variables.

Table4: Model Summary

Mode	R	R Square	Adjusted R Square	Sig. F Change
1	.837	.700	.651	.000

The table 5 shows the beta coefficients and Unstandardized Coefficients for the regression. This model includes all the potential independent variables that have been identified.

Table 5: Unstandardized Coefficients of Variables

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.747	.259		2.879	.006
	DUMMY MRP	-.034	.086	-.035	-.392	.697
	DUMMY INSPECTION	.059	.026	.268	2.276	.028
	DUMMY COST	.099	.039	.287	2.514	.016
	DUMMY QUALITY	-.008	.032	-.024	-.251	.803
	DUMMY STORAGE	.064	.037	.205	1.718	.093
	DUMMY WASTAGE	.145	.055	.286	2.629	.012
	DUMMY AVAILABILITY	-.046	.033	-.122	-1.400	.169

From Table 5, the regression equation is obtained as:

$$Y=0.747-0.034X1+0.059X2+0.099X3-0.008X4+0.064X5+0.145X6-0.046X7 \quad (2)$$

9. 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	1.53	1.565	0.0228
P2	1.483	1.509	0.0175
P3	1.589	1.618	0.0182
P4	1.305	1.358	0.0406
P5	1.58	1.6	0.0126

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

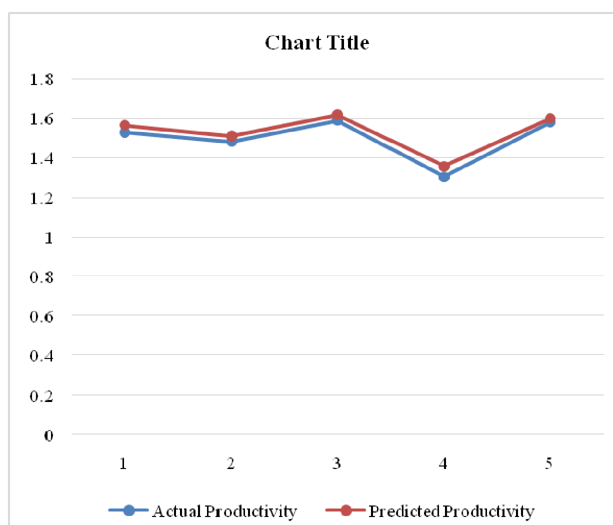

Figure 6: Comparison of predicted and actual productivity

10. 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),

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

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 very good agreement with the actual measurements.

Table 7: Statistical measures results

Measures	MAPE%	AA%	R	R^2
Results	2.24	97.76	0.837	0.700

11. CONCLUSION

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

1. The main factors affecting construction 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. Material productivity forecasting model has been developed with seven influential factors with coefficient of determination of developed model equal to 0.70.
4. Using linear regression technique gives average accuracy percentage 97.76%and mean absolute percentage error 2.24%.
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.

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