

Research Article

Estimating Productivity of Brickwork item using Logistic and Multiple Regression Approaches

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Abstract: Regression analysis of the most common techniques in estimating labor productivity rates in Iraqi construction projects. In the first part of this research has been identified the factors and variables are affecting to the brickwork productivity and most important of these variables the age, experience, high building, the number of workers and security condition of the site. One model was built for the prediction the labor productivity rates for brickwork item. The data used in this model was collected from construction project in Iraq. It was found that Multiple Linear Regression (MLR) have the ability to predict the construction productivity for brickworks with a good degree of accuracy of the coefficient of correlation (R) was 87.28%,and average accuracy percentage of 92.5%.In the second part of this research was development another mathematical model for the same variables using Logistic Regression Technique (LRT). Results of the study showed that the use of a binary logistic regression gave a logical response results are consistent with the studied casewith a moderate degree of average accuracy percentage of 95.8%.the application of Logistic Regression Technique, as a modern technique, in Iraqi construction project is necessary to ensure successful management, and many of the planners feel the need of such system in planning stage of construction project. Based on the foregoing, the study recommends expanding the use of logistic regression to estimate productivity.

Keywords: Multiple Linear Regression, Logistic Regression Technique, labor productivity rates.

INTRODUCTION

Productivity rates of construction trades are the basis for accurately estimating time and costs required to complete a project. Productivity could be defined as “the ratio of output of required quality to the inputs” for a specific production situation; in the construction industry, it is generally accepted as “work output per man-hours worked”. Improved productivity helps contractors not only to be more efficient and profitable; knowing actual productivity levels also helps them to estimate accurately and be more competitive during bidding for projects. In response to the industry needs, it is widely accepted that productivity measurement plays an important role in the construction management process. Productivity measurement provides the necessary data to analyze factors for project owners, constructors, and management professionals to control construction progress, estimate the cost of future construction projects, and determine its competitiveness in the global market [1].

RESEARCH QUESTION

Only One question raised in this study is: Is regression analysis technique can be applied in

construction sector in order to calculate the construction productivity rates of brickwork?

RESEARCH OBJECTIVE

The primary aim of this research was to conduct an accurate measurement of on-site construction productivity in Iraq through developing regression models for predicting the productivity of brickwork. Main aim of this research is to compare the accuracy of two estimating techniques; Multiple Linear regression and Logistic regression can be justified through the following procedure:

- Exploring the application of Regression Analysis Techniques (RAT) in construction productivity.
- Identify the factors that affect the brickwork productivity in construction project.
- Develop a mathematical models and numerical equations to compute the productivity of brickwork.
- Define the degree of accuracy for the mathematical models.

RESEARCH SIGNIFICANCE

This research provides a great benefit for researchers and academics in the field of scientific research, in addition to providing a great service for engineers and planners to estimate labor productivity for the task of brickwork according to accurate and easy to use equations.

RESEARCH METHODOLOGY

Research methodology has adopted to involve the following:

- **Literature Survey:** is to comprehensive review for the subject of construction productivity. Also exploring the application regression analysis technique in construction project. Literatures review involving references, dissertations, journal papers, textbooks and Internet publications relating to the subject of research especially which are related to construction productivity.
- **Data collection:** Researcher has been taking data from previous research titled "Factor Effecting Brickwork Productivity Estimating Using Artificial Neural Network" in the year 2011 [2].
- **Data analysis:** data analyses were conducted by using the statistical software package, Statistical Package for the Social Sciences, SPSS vr.20.0, for determining the productivity rate characteristics. Various statistical analysis methods including descriptive statistics, correlation
- **Developed Mathematical Models:** Based on the data analyses' results, it will provide Multiple Linear Regression and logistic regression models to predicting productivity of brickworks and discuss the results.
- **Conclusions, recommendations and future research:** Based on the results of the data analyses and developed model, conclusions and recommendations were provided for this research.

EXPLORE PREVIOUS STUDIES ON THE CONSTRUCTION PRODUCTIVITY

Researcher review of previous studies on the subject of production of construction and the last five years and as of 2010 so as to ensure the review of recent studies: Some studies dealing with learning curve theory and application [3,4]. Al-Zwainy [5] used Back-propagation Feed-forward neural networks for productivity estimation of the finishing works with stone tiles for building project. In this study, the researcher will be comparing the results of the two different methods to estimate productivity of marble finishing works for floors; these two methods are regression analysis and neural networks. For the subject of estimation construction productivity by neural

networks has been completed as an independent research and published in the ARPN Journal of Engineering and Applied Sciences, by the same researcher, Al-Zwainy [6]. In this study will be to predict construction productivity for the marble work item using multiple linear regressions and ANN, then a comparison between the two methods for the purpose of determining the most accurate method. One of the major studies and is the most comprehensive study on the subject of construction productivity[7][8]; first study aims at developing construction productivity estimating model for marble finishing works of floors using Multivariable Linear Regression technique (MLR). The model was developed based on 100 set of data collected in Iraq for different types of project such as residential, commercial and educational projects. These are used in developing the model and evaluating its performance. Ten influencing factors are utilized for productivity forecasting by MLR model, they include age, experience, number of the assist labor, height of the floor, size of the marbles tiles, security conditions, and health status for the work team, weather conditions, site condition, and availability of construction materials. One model was built for the prediction the productivity of marble finishing works for floors. It was found that MLR have the ability to predict the productivity for finishing works with excellent degree of accuracy of the coefficient of correlation (R) was 90.6%, and average accuracy percentage of 96.3%. This indicates that the relationship between the independent and independent variables of the developed models is good and the predicted values from a forecast model fit with the real-life data. Second study development a mathematical model for predicating the construction productivity of floor using artificial neural perception network, because the methods currently used to estimation the productivity such as the personal experience, is a traditional methods inaccurate. Therefore, it can be adopt new and advanced techniques to predicating the productivity construction with accurate, speed and ease of use. In this study have been identified ten independent variables effect on the construction productivity of floor, the data collection from construction project in Mosul (Iraq) through the design of the data collection form (Form measurement of work). In this research, one model was built for the prediction the total productivity of building project.

Ailabouni and Gidado [9] developed Regression models for predicting changes in productivity, when the underlying factors affecting productivity are varied. These factors were broadly categorized as general work environment, organizational work policies, group dynamics and interpersonal relationships and personal competence of the employees as applicable to the construction industry in the United Arab Emirates (UAE). The most significant factors amongst these were determined through three surveys using the Severity Index and Chi

Square computations for significance. The factors were regrouped into factors that afforded practical variation at site and productivity data was collected using different combination of the most significant factors of Timings, Supervision, Group Dynamics, and Control by Procedures, Climate and Material Availability. Construction activities such as Excavation, Formwork, Reinforcement, Concreting, and Block work, Plaster and Tiling were studied and the increase or decrease in productivity obtained was compared to the actual site average productivity; then analyzed statistically using the MINITAB 15 software, and linear regression models established. Validation was undertaken at four sites and it was observed that the regression models arrived at were capable of predicting productivity changes within $\pm 15\%$.

PRODUCTIVITY CONCEPT

Productivity is commonly defined as a ratio between the output volume and the volume of inputs. There are many types of productivity [10]:

- Single factor productivity. Productivity calculated for single activity like labor, concrete or equipment is known as single factor productivity.
- Multi factor productivity. Productivity calculated for more than one activity like labor and equipment or Material, labor & equipment and concrete is called multi factor productivity.
- Total Factor productivity. Productivity calculations which include all the activity on the construction site is called as total factor productivity.

REGRESSION ANALYSIS TECHNIQUES

Researcher reviewed in this paragraph the concept of regression, and why used regression, and what types of regression and how to choose the right type for each problem of research.

What is Regression Analysis?

Regression analysis is a form of predictive modeling technique which investigates the relationship between a **dependent** (target) and **independent variable** (s) (predictor). This technique is used for forecasting, time series modeling and finding the causal effect relationship between the variables. For example, relationship between rash driving and number of road accidents by a driver is best studied through regression [11].

Why use Regression Analysis?

There are multiple benefits of using regression analysis. They are as follows [11]:

- It indicates the significant relationships between dependent variable and independent variable.

- It indicates the strength of impact of multiple independent variables on a dependent variable.

How many types of regression techniques?

There are various kinds of regression techniques available to make predictions. These techniques are mostly driven by three metrics (number of independent variables, type of dependent variables and shape of regression line) [11].

Linear Regression

It is one of the most widely known modeling techniques. Linear regression is usually among the first few topics which people pick while learning predictive modeling. In this technique, the dependent variable is continuous, independent variable(s) can be continuous or discrete, and nature of regression line is linear. Linear Regression establishes a relationship between **dependent variable (Y)** and one or more **independent variables (X)** using a **best fit straight line** (also known as regression line). It is represented by an equation

$$Y = a + b * X + e \dots \dots \dots (1)$$

Where: a is intercept, b is slope of the line and e is error term.

Logistic Regression

Logistic regression is used to find the probability of event=Success and event=Failure. We should use logistic regression when the dependent variable is binary (0/ 1, True/ False, Yes/ No) in nature. Here the value of Y ranges from 0 to 1 and it can represent by following equation.

$$\text{Odds} = \frac{p}{(1-p)} = \frac{\text{probability of event occurrence}}{\text{probability of not event occurrence}}$$

$$\ln(\text{odds}) = \ln\left(\frac{p}{(1-p)}\right) = \text{Logit}(p) = \ln\left(\frac{p}{(1-p)}\right) = b_0 + b_1 X_1 + b_2 X_2 + b_3 X_3 \dots + b_n X_n \dots \dots \dots (2)$$

Where; p is the probability of presence of the characteristic of interest.

Important Points:

- It is widely used for **classification problems**
- Logistic regression doesn't require linear relationship between dependent and independent variables. It can handle various types of relationships because it applies a non-linear log transformation to the predicted odds ratio
- To avoid over fitting and under fitting, we should include all significant variables. A good approach to ensure this practice is to use a step wise method to estimate the logistic regression

- It requires **large sample sizes** because maximum likelihood estimates are less powerful at low sample sizes than ordinary least square
- The independent variables should not be correlated with each other i.e. **no multi collinearity**. However, we have the options to include interaction effects of categorical variables in the analysis and in the model.
- If the values of dependent variable is ordinal, then it is called as **Ordinal logistic regression**
- If dependent variable is multi class then it is known as **Multinomial Logistic regression**.

Others types of regression

There are other types of regression, including Polynomial Regression, Stepwise Regression, Ridge Regression, Lasso Regression and Elastic Net Regression

How to select the right regression model?

Within multiple types of regression models, it is important to choose the best suited technique based on type of independent and dependent variables, dimensionality in the data and other essential characteristics of the data. Below are the key factors that you should practice to select the right regression model [11]:

- Data exploration is an inevitable part of building predictive model. It should be you first step before selecting the right model like identify the relationship and impact of variables
- To compare the goodness of fit for different models, we can analyse different metrics like statistical significance of parameters, R-square, Adjusted r-square, AIC, BIC and error term. Another one is the Mallows' Cp criterion. This essentially checks for possible bias in your model, by comparing the model with all possible sub-models (or a careful selection of them).
- Cross-validation is the best way to evaluate models used for prediction. Here you divide your data set into two group (train and validate). A simple mean squared difference between the observed and predicted values give you a measure for the prediction accuracy.
- If your data set has multiple confounding variables, you should not choose automatic model selection method because you do not want to put these in a model at the same time.
- It'll also depend on your objective. It can occur that a less powerful model is easy to implement as compared to a highly statistically significant model.

- Regression regularization methods (Lasso, Ridge and Elastic Net) works well in case of high dimensionality and multicollinearity among the variables in the data set.

IDENTIFICATION OF MODEL VARIABLES

Five in depended variable were carefully selected. These independent variables can be classified into tow type, objective and subjective variable as show in Table (1).The ways these variable are represent fell in two groups. The first group (objective variables) comprised variable that are real number, for example "the age" the number of the objective variable is four (V₁,V₂,V₃ and V₄).The remaining variable (V₅) are categorical variable that represent on choice of categories. Each variable has been analyzed in order to determine the past way of representation for that variable in the modeling process.

Table-1: Description variables

variable	description	units	Type
V1	The age	Years	Objective
V2	Experiences	Years	Objective
V3	No. of worker	Number	Objective
V4	Level of execution	Meter	Objective
V5	security conditions	Category	Subjective

Table (2) shows the summary of statistical analysis

Table-2: Summary of actual data

parameter	V1	V2	V3	V4	V5
Max.	55	32	8	3	1
Min.	22	4	4	1	1
Range	33	28	4	2	0
average	37.92	15.2	5.64	1.62	1

DEVELOPMENT of BRICKWORK PRODUCTIVITY by MODEL USING MULTIPLE LINEAR REGRESSION.

The Statistical Package Society Sciences Solutions Services (SPSS) software; Vertion.23 is used to develop the model. SPSS statistical tool was employed to perform regression analysis, as following steps:

1) Steps one: Editing Data

In this step, the researcher used SPSS statistical software for obtained the constants:

a) Input data

Figure (1) shows the all variables (dependent and independents)

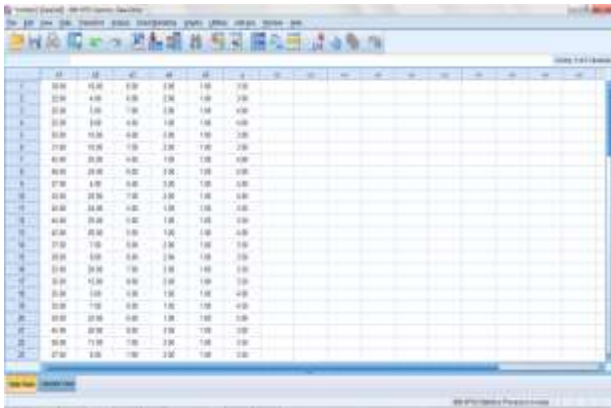


Fig-1: Step one in MLR

b) Select regression analysis
 Researcher goes to menu bar and chooses analyze then choose regression then select linear, as shown figure (2).



Fig-2: Step two in MLR

c) Researcher chooses the dependent and independent variable, as shown figure (3).



Fig-3: step three in MLR

d) Researcher click statistics and choose model, R squared, descriptive, part and partial correlations then click continue, , as shown figure (4).

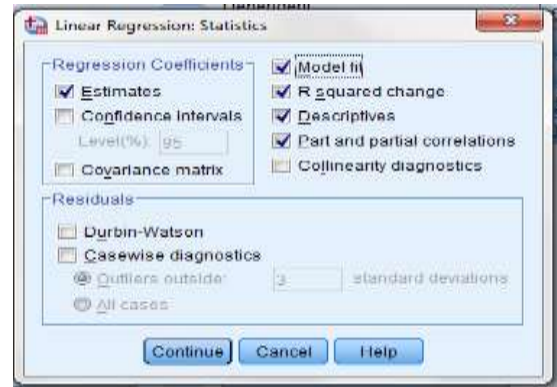


Fig-4: step four in MLR

e) Researcher chooses Enter method and click ok, as shown figure (5).



Fig-5: Step five in MLR

2) Steps two: Results

In this step, the researcher has the final result for regression analysis; the first table shows the mean and standard deviation and number for each variable show in table (3), and the correlation between all variables shows in table (4).

Table-3: Descriptive statistics

Variables	Mean	St.deviation	N
productivity	3.9500	.50760	50
age	37.9200	9.55295	50
experiences	15.2000	7.87142	50
no. of labour	5.7800	1.01599	50
level	1.3800	.53031	50
security	1.0000	.00000	50

Table-4: Correlations coefficient

	prod activ ity	age	experie nce	no. labour	Level	security
Productivity	1.000	.504	.291	-.319	-.610	.
Age	.504	1.000	.760	-.141	-.421	.
Experience	.291	.760	1.000	-.201	-.292	.
no. labour	-.319	-.141	-.201	1.000	.499	.
Level	-.610	-.421	-.292	.499	1.000	.
Security	1.000

Table (5) shows the correlation coefficient and the sig. is less than 0.05 so is good. Results of coefficient of correlation and (coefficient of determination) show that there is a moderate correlation between brickwork productivity and other input variables. This indicates a acceptance relationship between dependent and independent variables.

Table-5: Model summary

Model	R	R Square	Adjusted R Square	Sig. Change
1	.682	.466	.418	.000

The last table (6) is very important and shows the beta coefficients and Unstandardized Coefficients for the regression. it notice that the last variable (X5)(security condition) neglected because is constant for all location. The model appears to be useful for predicting the brickwork productivity. This model included all the potential independent variables that have been identified. From the last table we obtained this regression equation

$$y = 4.010 + 0.025X_1 - 0.013X_2 - 0.038X_3 - 0.417X_4 \dots\dots\dots (3)$$

Table-6: Unstandardized Coefficients of variables

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. E.			
(Constant)	4.010	.432		9.279	.000
age	.025	.010	.466	2.584	.013
experiences	-.013	.011	-.206	-1.205	.234
no. labour	-.038	.064	-.077	-.597	.554
level	-.417	.133	-.436	-3.134	.003

DEVELOPMENT of BRICKWORK PRODUCTIVITY by MODEL USING LOGISTIC REGRESSION

This model is one of the viable models convertible into linear models and that there is a relationship between the variable response and a number of explanatory variables, which is believed to have a significant effect on the probability of response and the fact that bilateral response, the variable authorized him two values either success probability (p) or failure probability (1-p) so it follows Bernoulli distribution. [12]

Where that:

$$P(X_i) = \frac{e^{\beta_0 + \sum \beta_i x_i}}{1 + e^{\beta_0 + \sum \beta_i x_i}} \dots\dots\dots (4)$$

To facilitate the above sample solution is transferred to a linear function.

$$\ln \frac{p}{1-p} = \beta_0 + \sum \beta_i x_i \dots\dots\dots (5)$$

SPSS statistical tool was employed to perform regression analysis, as following steps:

1) Steps one: Editing Data

Figure (6) shows the all variables (dependent and independents)

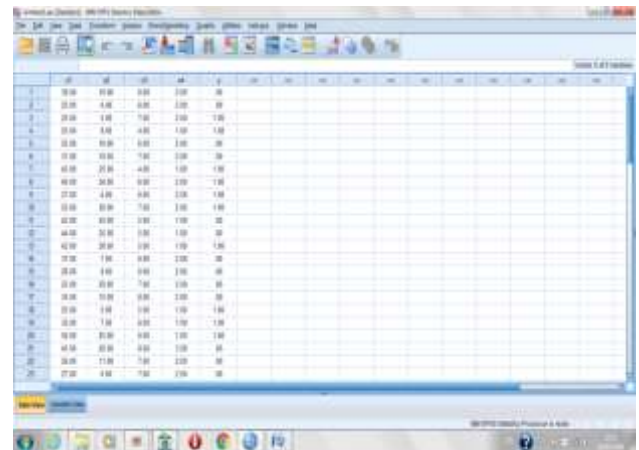


Fig-6: Step one in LMLR

b) Select regression analysis

Researcher goes to menu bar and choose analyze then choose regression then select binary logistic, as shown figure (7).

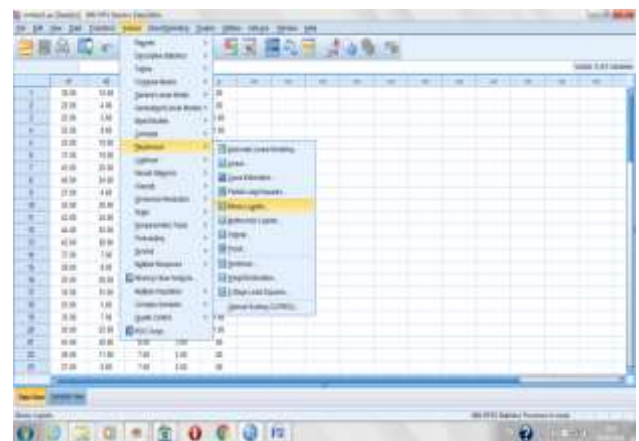


Fig-7: Step two in LMLR

c) Researcher chooses the dependent and Covariates variable, as shown figure (8).

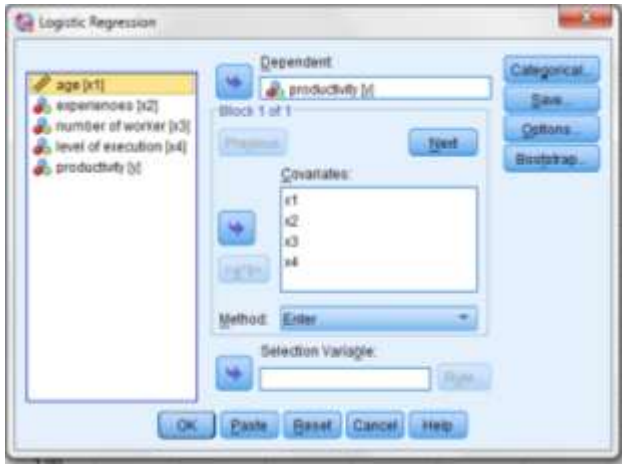


Fig-8: Step three in LMLR

d) Researcher click options and choose, hosmer_lemes how goodness and correlations of estimates Then click continue, as shown figure (9).

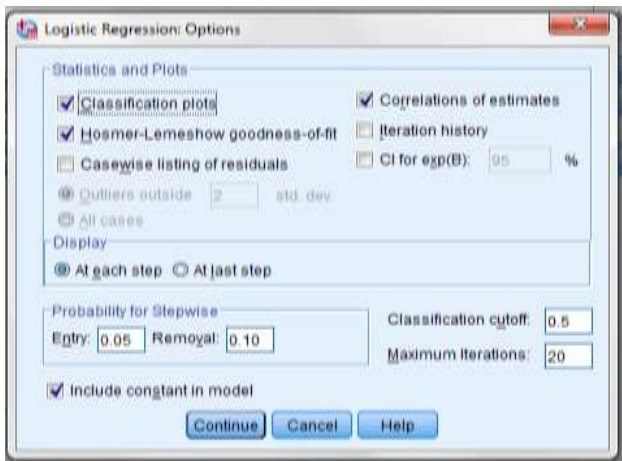


Fig-9: Step four in LMLR

e) Researcher chooses Enter method and click ok, as shown figure (10).



Fig-10: Step five in LMLR

2) Steps two: Results

Using the software package ready SPSS and using the Enter method and after the data is encoded and processed and entered into the computer and choose analyze it then sub regression then binary logistic then ok .we got to the beginning of the descriptive information of the sample are summarized in Table (7).

Table-7: Case processing summary

Unweighted Cases ^a		N	Percent
Selected Cases	Included in Analysis	50	100.0
	Missing Cases	0	.0
	Total	50	100.0
Unselected Cases		0	.0
Total		50	100.0

a. If weight is in effect, see classification table for the total number of cases.

Summarizes in Table (7) the data entered in the analysis and the size of the studied sample and missing data. The table (8) represents the values of the dependent variable symbols.

Table-8: Dependent variable encoding

Original Value	Internal Value
bad	0
good	1

Table (9) includes all estimated model parameters and Standard error for each parameter.

Table 9: Variables in the Equation

Step 1 ^a	B	S.E.	Wald	df	Sig.
x1	.166	.103	2.627	1	.105
x2	-.193	.122	2.497	1	.114
x3	-.095	.494	.037	1	.847
x4	-3.204	1.172	7.467	1	.006
Constant	3.257	3.724	.765	1	.382

a. Variable(s) entered on step 1: x1, x2, x3, x4.

Calculable Wald for each parameter of the model and the number of degrees of freedom either in the adequacy and goodness of the model we used in calculable R² in the linear regression either in the case of logistic model are used to the greatest possible proportion of which follows the distribution (chi-square X²). The value(X²=25.928) a moral at the significance level is less than 0.001 as sig equal zero Which confirms the moral model fully conciliator as the gap shown in the table (10) to df equal 4 the number of variables entered.

Table 10: Omnibus tests of model coefficients

		Chi-square	df	Sig.
Step 1	Step	25.928	4	.000
	Block	25.928	4	.000
	Model	25.928	4	.000

The Table (11) represents a test No parametric of the model depends on the value of (X²) of the difference between the values seen and projected values.

Table-11: Contingency Table for Hosmer and Lemeshow Test

		productivity = bad		productivity = good		Total
		Observed	Expected	Observed	Expected	
Step 1	1	4	4.419	1	.581	5
	2	3	3.405	2	1.595	5
	3	4	3.178	1	1.822	5
	4	1	1.416	4	3.584	5
	5	2	.578	3	4.422	5
	6	0	.349	5	4.651	5
	7	0	.272	5	4.728	5
	8	0	.201	5	4.799	5
	9	0	.136	5	4.864	5
	10	0	.045	5	4.955	5

From the table (9) can be obtained this equation

$$\log \frac{P}{1-P} = 3.257 + 0.166X_1 - 0.193X_2 - 0.095X_3 - 3.204X_4 \dots \dots \dots (6)$$

Where (P) represent the probability of success of the model.

The results of (Cox and Snell R Square) equal to 40.5% and (Nagelkerke R square) equal to 58.3%, this results show that there is a acceptance correlation between construction productivity and other input variables.

VALIDATION REGRESSION MODELS

In this research, the important method is employed (Collection of new data to check the model and its predictive ability). Five new observations for each variable were collected as shown in table (12). And table 13. These observations which were not included in the model calibration procedures were used as independent verification check and comparison of results with the actual productivity of brickwork and the predicted productivity values

Table-12: Number of observations for each variable for MLR model

Project No.	V1	V2	V3	V4	V5
P1	30	10	6	2	1
P2	22	4	6	2	1
P3	25	5	7	2	1
P4	25	8	4	1	1
P5	25	10	6	2	1

Table 13: Number of observations for each variable for LMR model

No. Project	V1	V2	V3	V4
P1	44	25	5	1
P2	31	5	5	1
P3	50	15	5	1
P4	45	15	6	1

The summary of computing brickwork productivity by MLR for verification of estimating models is show in Table (14). Where second column presents actual productivity and third column present estimate productivity for 5 reaming observation after applying regression equation on it where regression equation obtain by SSPS program.

Table 14: Brick work productivity computed by MLR

Col. 1	Col. 2	Col. 3	Col.4
Project number	actual productivity	Estimate productivity	2-3 /2
P1	3.5	3.568	0.019429
P2	3	3.446	0.148667
P3	4	3.470	0.1325
P4	4	3.962	0.0095
P5	3	3.443	0.147667

The summary of computing brickwork productivity by LMLR for verification of estimating models is show in Table (15). Where column two presents actual productivity and column 3 presents estimating productivity and column 4 present the probability of success for 4 reaming observation after applying regression equation on it where regression equation obtain by SSPS program.

Table (15) Brick work productivity computed by LMR

Col. 1	Col. 2	Col. 3	Col. 4
Project number	Actual Productivity	Estimating Productivity	Prob. Success
P1	3.5	2.057	88.6%
P2	4.5	3.942	98.04%
P3	5	4.983	99.3 %
P4	4	4.058	98.3%

The comparison between the predicated Productivity and actual productivity for brickwork is plotted in Figure-5 and figurev6. For MLR and LMR respectively, it is clear from this Figure, the ability of multivariable linear regression technique to predict the productivity of marble finishing works for floors for any of data set within the range data used in developing the multivariable linear regression approach.

The coefficient of determination (R²) is (76.19%) for MLR model and (83.04%) for LMR model, as shown in figure-11 and figure 12, therefore it

can be concluded that ANN models show very good agreement with actual measurements

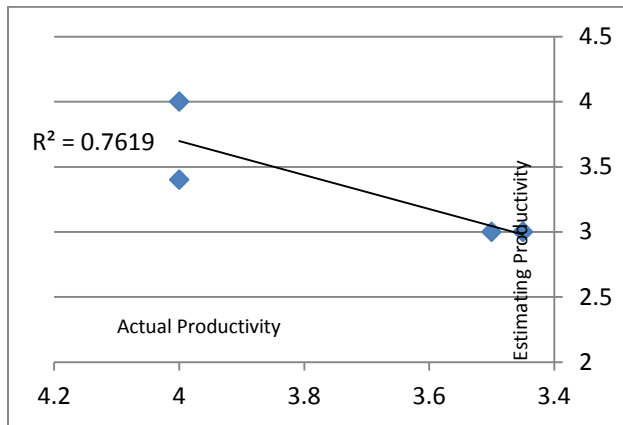


Fig-11: Comparison of predicted and observed productivity for MLR model.

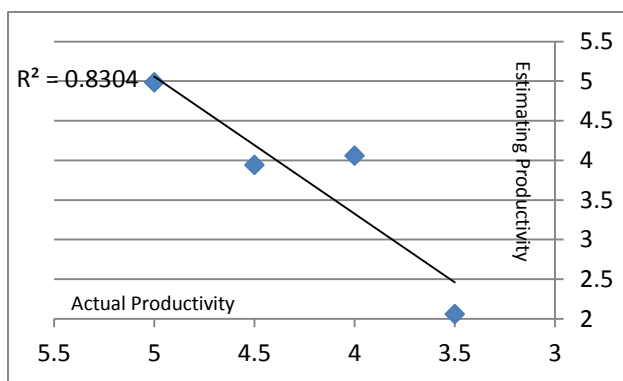


Fig-12: Comparison of predicted and observed productivity for LMR model.

The researcher will use the four statistical equations to examine of MLR model as shown in table (16)

Table-16: Result of the comparative study

Description	MLR model	LMR model
MAPE	7.5%	4.2%
AA%	92.5%	95.8%
R	87.28%	91.1%
R ²	76.2%	83.0%

CONCLUSIONS

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

- Five in depended variable were carefully selected. These independent variables can be classified into tow type, objective and subjective variable such as Age , Experiences, no. of labour, Level of execution and Security conditions.
- In this instance multiple liner regression will be used to determine the statistical relationship

between response actual productivity) and explanatory variable.

- Using linear regression technique gives average accuracy percentage 92.5%and mean absolute percentage error 7.5%.
- Using logistic regression technique gives average accuracy percentage 95.8% and mean absolute percentage error 4.2%.
- Results of the study showed that the use of a binary logistic regression response, gave a logical outcome Consistent with the theory behind the phenomenon studied.

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