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MATHEMATICAL TIME-COST MODEL FOR INSTITUTIONAL BUILDING PROJECTS IN NIGERIA

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ABSTRACT

The accurate prediction of construction time at the early project stage is essential to incorporate realistic project duration in the bid package. The study investigates the application of the Bromilow's Time-Cost Model (BTC) to predict the construction duration of institutional building projects in Nigeria. Sixty (60) completed project data were used for the analysis. Linear regression was performed to explain the linear relationship between cost and time variables of the data. The result indicates a strong linear relationship between construction cost and construction duration with coefficients of correlation R= 0.808 and coefficient of determination R^2 = 0.670. Double log (log-log) regression was also employed in the form of the BTC model to determine the values of K and β which indicate general level of time performance and the sensitivity of the time performance affected by project size as measured by cost respectively. The low K value of 20.1 demonstrates that the time performance of the construction industry has improved compared to previous surveys while β value of 0.686 indicates a greater influence of project complexity on time prolongation. The model also showed a good fit to the data with R value of 0.845 and R^2 value of 0.716. The model showed a satisfactory prediction performance with MAPE of 13.6% over the test sample.
Keywords: *Time-Cost, Cost, duration, Bromilow model, regression.*

INTRODUCTION

The performance of any construction project is basically measured in terms of how well it is completed according to its schedule, budget (cost) and desired quality standard. Timely completion of a construction project is frequently seen as a major criterion of project success by clients, contractors and consultants alike. Construction cost and time according to [1] and [2] are two key elements to determine the success of project. In general, the more resources assigned to a project the less time it will take to complete the activity but the cost is usually higher in such cases. This trade-off between time and cost give construction planners both challenges and opportunities to work out the best construction plan that optimize time and cost to complete a project. Client's objectives can also be achieved through the management effort that recognises interdependences of time, cost and quality [3]. Therefore there is an increasing need for the prediction of construction time at the planning and bid preparation stages in order to include realistic project duration in the bid package. Despite the importance of completing a construction project with predicted cost and quality standards, Construction Time Performance (CTP) according to [4] remains a crucial success factor for a construction project as project delays could also lead to cost overrun and poor quality. Construction delays emanate from a diversity of origins including contractors fault, changes in design and other unforeseen events such as inclement weather and industrial relation disputes or just simply an overly optimistic predetermined contract duration [5]. Delay occurs in every project and the magnitude varies considerably from project to project. Building projects according to [6] in Nigeria are completed at duration much longer than their earlier planned durations. This was also corroborated by [7] who asserted that delay in project execution is a major problem in the Nigerian construction industry because almost all projects are completed beyond their planned completion dates. The problem of delay and time overrun according [8] is of international concern. Seven-eight of building contracts surveyed in Australia were completed after schedule [9]. 37% of projects in Saudi Arabia were subject to delay [10]. Building projects executed in Lagos metropolis experience an average delay of 51% of planned duration of most projects [11]. Construction prediction models can easily be developed where a completed project database is available. Contractors usually use previous experience to estimate the project duration [12]. Project planners according to [13] estimate project duration using the lump sum method without taking into consideration real performance possibilities within the given deadline. These calls for pragmatic mathematical models for rapid construction time estimation in Nigeria.

THEORETICAL BACKGROUND

A relationship between construction cost and the time taken to complete a construction project was first mathematically established by [14] and subsequently updated by [15]. The equation describing the mean construction time as a function of project cost was found to be

$$T = K \times C^{\beta} \qquad \text{(i)}$$

Where; T = duration of construction period from the date of possession of site to substantial completion in days.

C = completed cost of project in millions of Australian dollars adjusted to constant labour and material prices.

K = a constant indicating the general level of time performance per million Australian dollars and β = a constant describing how the time performance is affected by the size of the construction projects measured by the cost. The model demonstrates that the project is basically a function of its total cost. It therefore provides the basis for all parties concern with the construction process to establish a fairly accurate probable duration of a project in days. Similar studies have been conducted to calibrate the BTC model. Some of these are [16] in United Kingdom; [17] in Honk Kong; Yeong [18] in Malaysia; and [8] in Nigeria. The BTC model was replicated by [12] using 55 residential building project data in Texas. The result of the study indicated that the BTC model holds a good prediction for the Texas construction industry at the level of significance (p value) < 0.0001. The BTC model was validated by [8] using different categories of building project data. They discovered that the BTC model has a poor prediction capability for both private and public project data with R and R^2 values of 0.453 and 0.205 respectively. This study attempts to develop a pragmatic mathematical Time-cost relationship for predicting durations of institutional building projects in Nigeria. This would be useful to both clients and contractors for determining realistic construction duration at the early project phase.

RESEARCH METHODS

The data for the research was obtained through a self administered questionnaire. Sixty (60) completed institutional building project data was obtained from the records of contractors, clients and consultants. The data were limited to building projects executed between 1999 and 2008 in the North-Eastern geopolitical zone of Nigeria. All the cost data were adjusted to prices of 2005 to take care of difference in time and location. The Double log regression model as established by Bromilow (1969) was employed for the analysis. The model is represented by:

$$lnT = lnK + \beta lnC \qquad \text{(ii)}$$

Where; T, K, β and C are as described in (i) above

Statistical software SPSS for windows was employed for the analysis. The model was validated using twelve (12) completed project dataset. The performance of the model was determined by calculating the Mean Absolute Percent Error (MAPE) given by the relation:

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{Actual_i - Predicted_i}{Predicted_i}\right| \times 1000 \qquad \text{(iii)}$$

RESULTS AND DISCUSSION

Linear Regression: Linear regression analysis was performed to examine the relationship between actual construction cost and construction time. The scatter plot presented in Fig.1 indicates a good fit of the data. The x axis of the plot represents the construction cost in millions of Naira while the y-axis represents construction duration in working days. The plot indicates that the project completion time is positively related to the project construction cost at ($p<0.0001$).

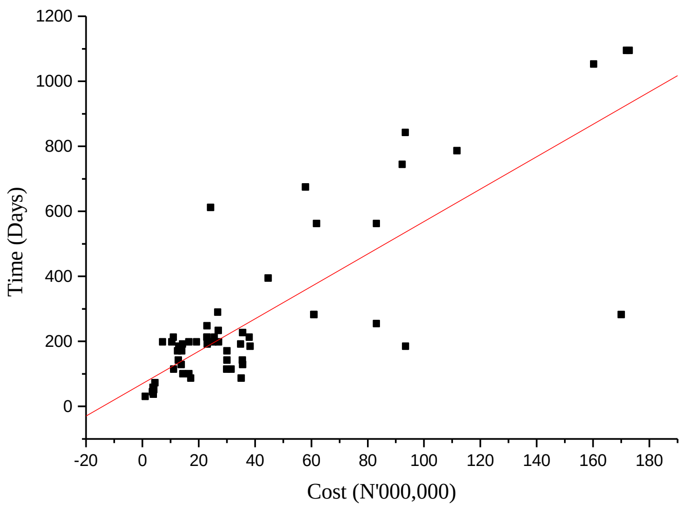

Fig. 1 Scatter Plot of the Linear Regression between Cost and Time

The results of the regression presented in table1 revealed that there is a strong linear relationship between actual construction costs and completion time with correlation coefficient R = 0.8186 and coefficient of determination R^2 = 0.6702 and adjusted R^2 =

0.6which indicates that more than 67% of the variability is accounted for by the linear model.

Table 1 Summary of Regression Result

R	R^2	Adj. R Square	Std. Error	R Square Change	F Change	Sig. F Change
0.8186	0.6702	0.6647	153.333	0.670	115.863	<0.0001

BTC Model for the Data: Transformed (log-log) regression analysis was performed on the data. The equation of the log-log model was written in the logarithmic form:

$$lnT = lnK + \beta lnC$$

The result of analysis is presented in Table 2.

Table 2 Summary of log-log Regression

Parameter	Value
Ln K	3.042
K	20.91
Β	0.686
R	0.845
R^2	0.715
Adj R^2	0.709
F	142.671
Sig F	<0.0001
RMSE	0.468

The result of the BTC model showed that the model has a high predictive efficacy with R^2 value of 0.715 this means that more than 70% of the variability of the data is accounted for by the model. The Time-Cost relationship of institutional building projects in Nigeria can be examined using the BTC model. It can be expressed as

$$T = 20.91 \times C^{0.686}$$

The K value of 20.1 indicates that for a project of average cost of ₦1 million, the construction time is 20.91 days for project completion. This value further demonstrate an increase in the performance of the construction industry when compared to values obtained from early studies of 63 and 65 for private and public projects respectively by Ogusemi and Jagboro (2006). The β value which describes how the time performance was affected by project size as measured by cost (Bromilow *et al.,* 1988) was determined to be 0.686. This larger value of β demonstrates somewhat a greater influence of project complexity on time prolongation. This implies that for an institutional building in Nigeria, an increase in the construction cost results in a corresponding increase in the construction time. The regression plot for the log-log relationship is presented in Fig. 2 which also shows a strong relationship between the variables. The model would be useful for both contractors and clients for predicting the average completion time of institutional building projects in Nigeria.

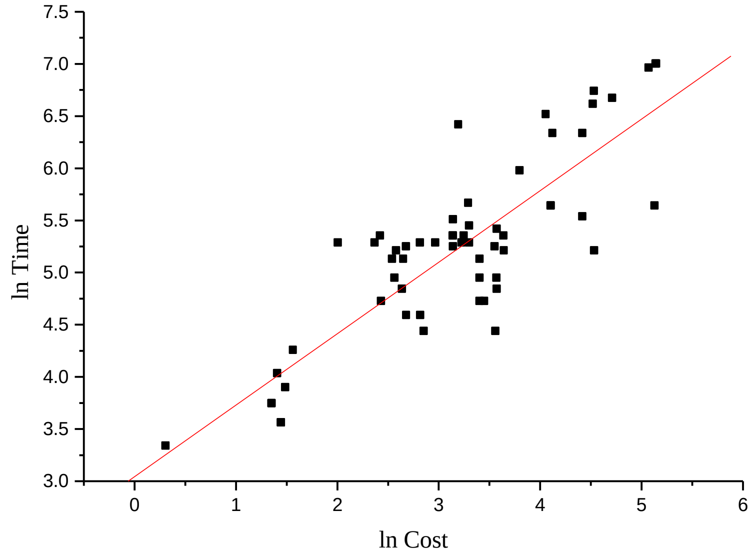

Fig. 2 Linear Plot of log-log regression

Evaluation of Model

The predictive ability of the Time-Cost model is evaluated over the test sample of 12 completed project data. The result of the prediction performance is presented in Table 3.

Table 3. Prediction Performance of Model

S/No	Final Cost (₦'Million)	Actual Duration (Days)	Predicted Duration (Days)	Prediction Error (%)
1	11.77422	108.5	113.5046	-4.4092
2	13.28808	117.8	123.3245	-4.4796
3	28.96434	201.5	210.4711	-4.2624
4	20.72356	155	167.2817	-7.3419
5	22.352	139.5	176.1915	-20.8248
6	15.63547	102.3	137.8841	-25.8072
7	16.23649	117.8	141.4984	-16.7482
8	16.44269	139.5	142.7288	-2.622
9	23.35497	145.7	181.5776	-19.7588
10	11.66747	130.2	112.7977	15.4279
11	16.82996	108.5	145.0264	-25.186
12	34.14809	210.8	235.637	-10.5404
Max. Error				**15.42%**
Min. Error				**-25.80%**
Ave. Error				**10.08**
MAPE				**13.08%**

The Mean Absolute Percent Error of the model is calculated from the relation as
$MAPE = 13.08\%$

CONCLUSION

The BTC model has been used by practitioners in some countries for preliminary estimation of the construction duration based on the construction cost. The result of statistical analysis on the cost and time data showed a strong linear relationship between the variables. The results further showed that for an institutional building project in Nigeria, an increase in construction cost results in an increase in the completion time. For a project of average construction cost of ₦1Million, the result revealed that the construction time is 20.91 days. This is an improvement in the performance of the construction industry compared to the time performance obtained from previous studies. From the findings project complexity has a greater influence on the construction time prolongation. The study was limited to investigate the effect of construction cost on construction time in the context of institutional building projects in Nigeria. The inclusion of other variables such as productivity, management attributes and project environment will have a far reaching effect on the efficacy of the model. The Time-Cost model is useful for both contractors and clients to predict the mean time required to deliver a project when the cost is known. It provides an alternative to supplement the prevailing practice of estimating construction time based on individuals experience.

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