Bromilow's Construction Cost And Time Relationship Model Validation For Construction Project Delivery

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Abstract- The objective of the study is to develope construction time - cost relationship model of building constructed in Addis Ababa, to determine how the general level of time performance of building construction projects are affected by it cost and size. Predicting project duration with reasonable accuracy is a formidable challenge to industry practitioners and alike. Consequently, several research studies have focused on this subject, and thus multiple models have been developed. Notwithstanding the conflicting findings of its predictive ability, the 50-year-old "time-cost" model of Bromilow (BTC) remains the baseline, to which the outcomes of most developed models are compared. The objective of this study, therefore, is to examine the validity, and hence the applicability, of the BTC model to estimate contract durations for building projects in Addis Ababa, in this regard, relevant data for fifty buildings in Addis Ababa, which were completed during the period 2010 and 2020 Gregorian calendar were collected. The results of the analysis show the BTC model holds true for the projects under the study, a model with a better statistical significance was developed with construction cost as a sole predictor variable. The ρ-value and F-value for the BTC was 0.000 and 36.09 respectively Furthermore, the adjusted R square for the BTC was 0.403 while that of the developed model was 0.445 which implies the developed model was a better fit for the data set. In addition, the developed models were validated by using two standard error measures of RMSE and MAPE which were found to be 84.46 days and 8.49% which implies the model is almost accurate forecasting.

Indexed Terms- Bromilow's Time Cost model, Construction Cost, Construction Duration, Regression Analysis

I. INTRODUCTION

Professionals and researchers have long recognized the significance of time and cost of construction as significant to project feasibility assessment and budget allocation decisions. Hence, it is basic for clients and contractors to obtain reliable and accurate estimates of both time and cost at the planning and initiation phase of a project. The development of construction time predicting models commenced with the use of project scope factors. Project scope is a measure of project size, which can be described as construction cost, project duration, gross floor area, number of stores, building type and procurement method.

The construction stage of a building project can be broadly partitioned into four main phases: site preparation, excavation, structural work (underground/aboveground), and finishing work. All the four stages are basic and must be arranged and facilitated as accurately as conceivable: in this way, the entire time required to total each stage is an important factor to consider during the planning phases of construction.

Construction time and delay has been a major concern to all stakeholders in the construction industry around the world because contract time overrun is a common issue that increments contractor's costs in this reducing profit margin and reputation and incur clients in additional holding charges, professional fees and income lost through late occupancy. They also increase the likelihood of contractual disputes.

Estimating time and cost is an important mission in the early phase of a construction project, especially in feasibility study. It provides a foundation for making decision whether or not the project is performed on schedule and within budget. Thus, reliability of this estimate will play a key role in measuring the success of building projects in Addis Ababa.

This research focus is on developing model for the prediction of building construction time in Addis Ababa using a set of completed projects database including construction cost and building type. The numerical condition that will be utilized is Bromilow's time -cost equation.

1.1 Objectives
The principal objective of this study is to validate Bromilow's model that can be used to estimate duration of building projects constructed in Addis Ababa.

Specific objectives

- To determine constant coefficients identifying the effect of project cost and size on general level of time performance.
- To determine how the general level of time performance of building construction projects is affected by its cost and size.
- To validate construction time - cost relationship model of building constructed in Addis Ababa

II. METHODOLOGY

Materials that has been used when conducting the researches includes glass bottles, measuring cylinder; pH meter; conductive meter; direct reading spectrometer (DR 2000), glass beaker & glass road.

The researcher uses both exploratory and descriptive way of expressions to reach at a reasonable conclusion and achieving the thesis objectives.

2.1 Data collection methods
For this study the following data collection methods have been employed:
The data source for this study is that of secondary data. A thorough literature review was carried out to assemble the theoretical framework for the study by reviewing similar works done and establish the parameters to be used as inputs in the development of the model. Furthermore, archival analysis of project records was carried out at relevant government, consulting and contractor offices to gather data on the parameters to be used in the development of the model. The sampling method used is stratified and random sampling. Survey and questionnaires are used to collect and record information from different government and private organizations. In this regard, the population of the study, as the title indicates, is completed building projects in Addis Ababa and the data are randomly collected from each sub-city of the Addis Ababa.

2.2 Data analysis
The collected data were analyzed by using statistical package for social sciences (SPSS) version 25.

2.3 Data presentation
Once the data has been analyzed the next step was presenting the data in a clear and concise manner, the researcher uses figures and tables which have been generated by SPSS and Microsoft Excel.

III. RESULT AND DISCUSSION

3.1 Result of unadjusted data
The scatter plot diagram among the dependent and independent variables indicates the independent variables are distributed by showing non-linearity of the unadjusted data for both contractual and actual data as shown in Figure1 and Figure 2

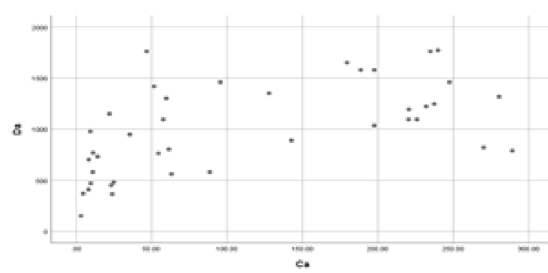

Figure 1 Scatter plot for unadjusted actual data

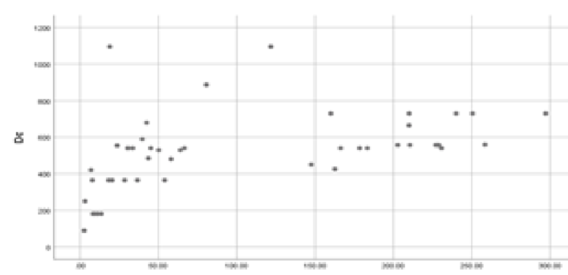

Figure 2 Scatter plot for unadjusted contractual data

Table 1 Correlation between actual cost and duration data

		Da	Ca
Da	Pearson Correlation	1	.572**
	Sig. (2-tailed)		.000
	N	40	40
Ca	Pearson Correlation	.572**	1
	Sig. (2-tailed)	.000	
	N	40	47

Table2. Correlation between contractual cost and duration data

		Da	Ca
Da	Pearson Correlation	1	.572**
	Sig. (2-tailed)		.000
	N	40	40
Ca	Pearson Correlation	.572**	1
	Sig. (2-tailed)	.000	
	N	40	47

The correlation between the two actual data variables is shown above in Table 2 and the correlation coefficient becomes 0.572 for the unadjusted data. For contractual data the correlation between contractual cost and contractual duration becomes 0.461. The result from both indicates that strength of correlation is categorized under moderate degree of relationship and there is better correlation for actual cost and duration of the projects than the contractual data.

3.3 Result of transformed data

The transformation of the data into natural logarithm form has resulted in a considerable increase in the coefficient of correlation. The correlation coefficient for contractual and actual data of the variables become 0.667 and 0.706 respectively. The result indicates that contractual cost and duration are under high degree of correlation and actual cost and duration are under moderate level of correlation. The association between the variables increases because of the data transformation.

The transformation of the data set into logarithmic form not only increased the value of the coefficient of correlation, but also enhanced the linearity of the relationship between each independent variable and the dependent variable for both contractual and actual data.

Table 3 Correlation Matrix for Transformed actual data

		LnDa	LNCa
LnDa	Pearson Correlation	1	.667**
	Sig. (2-tailed)		.000
	N	47	47
LNCa	Pearson Correlation	.667**	1
	Sig. (2-tailed)	.000	
	N	47	47

Table 4. Correlation Matrix for Transformed contractual data

		LnDc	LnCc
Ln Dc	Pearson Correlation	1	.706**
	Sig. (2-tailed)		.000
	N	47	47
Ln Cc	Pearson Correlation	.706**	1
	Sig. (2-tailed)	.000	
	N	47	47

3.4 BTC model

The BTC model, based on the power function is transformed into a linear form by the natural logarithm form as shown below.

$$\ln(T) = \ln(k) + \ln B(C)$$

In order to test the reliability of the developed model to predict project duration realistically, 47 of the projects were randomly selected from which the 35 public and 12 private building were used for model development while two public and one private building projects were used for model validation. Accordingly, the data transformed into natural logarithmic form corresponding to duration and cost was then fixed to the above simple linear regression form. The model was developed by using SPSS version 25.

Table 5. Model Summary - BTC Actual Data

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.667	.445	.432	.403

Table 6. Model Summary - BTC Contractual Data

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.706[a]	.499	.488	.360

Table 7. BTC Actual Data

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	5.851	1	5.851	36.009	.000[b]
	Residual	7.312	45	.162		
	Total	13.163	46			

Table 8. BTC Contractual Data

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	5.822	1	5.822	44.826	.000[b]
	Residual	5.844	45	.130		
	Total	11.666	46			

Table 9. Model Coefficients – BTC Actual Data

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	T	Sig.
1	(Constant)	5.718	.200		28.557	.000
	LNCa	.280	.047	.667	6.001	.000

Table 10. Model Coefficients – BTC Contractual Data

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	5.050	.171		29.572	.000
	LnCc	.272	.041	.706	6.695	.000

The above sets of results were selected on account of their relevance to describe the developed model. The first table shows the value of R and R^2 which show the goodness of F, while the second and third result show the significance value and the regression coefficients for actual and contractual data respectively.

The resulting regression equation for actual data based on the model coefficients shown in Table 4.12

$Y = 5.718 + 0.280x$

K is calculated as

$K = e^{5.718} = 2.718^{5.718} = 304.12$

Thus, the non-linear form of the BTC

$T = 304.12C^{0.280}$

T – Actual Project Duration in days; and

C – Actual Project Cost in millions of Ethiopian Birr

The resulting regression equation for actual data based on the model coefficients shown in Table 4.13

$Y = 5.050 + 0.272x$

K is calculated as

$K = e^{5.050} = 2.718^{5.050} = 156.02$

Thus, the non-linear form of the BTC

$T = 156.02C^{0..272}$

T – Contractual Project Duration in days; and

C – Contractual Project Cost in millions of Ethiopian Birr

The correlation coefficient for the model is 0.667 and 0.706 for actual and contractual data which is categorized under moderate degree of association. The analysis result indicates 66.7% and 70.6% & of estimation of construction duration is dependent on the corresponding construction cost for actual and contractual data respectively. Therefore, null hypothesis two is failed and Bromilow's equation is applicable to develop relationship between construction duration and cost.

3.5 Model Validation

Two standard error measures, namely Root Mean Square Error (RMSE) and Mean Absolute Percentage Error (MAPE). The closer the error values are to zero, the more accurate the model forecasts are. As described above, out of the fifty project whose data had been collected under this study, fortyseven of them were used for the model development and three were reserved for the validation of the model

Table 11. Actual Duration of Projects used for calibration.

Item No	Project Name	Ca(Million ETB)	Da(Days)	Dmodel(Days)	RMSE (Days)	MAPE (%)
1	Education Bureau Building	66.47	1085	984.87	87.46	8.49
2	W/ro Huluye Mixed use Apartment 2B+G+13	111.05	1033	1137.08		
3	Akaki TVET Building	19.07	740	984.87		

The analysis result shows MAPE value of 8.49% for actual and 1.03% for contractual data which shows the BTC model developed in this research is categorized as highly accurate forecasting as categorized in table 4.17 below. The RMSE values are 87.46days and 65.58days for actual and contractual data and the result indicates that the model has reasonable margin of error.

IV. CONCLUSION AND RECOMMENDATION

- Conclusion

The main objective of this study is to validate a model that can be used to estimate duration of building projects constructed in Addis Ababa using Bromilow's empirical equation. From the result it is proved that BTC model is applicable for building projects in Addis Ababa and there is a significant relationship between time performance of project and its cost.

Fifty building data were used to test the hypotheses and the corresponding null hypothesis was rejected and the formula based on the BTC was generated and is expressed as

$T = 304.12C^{0.280}$ for actual project data

$T = 156.02C^{0.272}$ for contractual project data

The validated BTC model were found to be more statistically significant. The ρ-value for actual and contractual data is 0.000. The F value for actual and contractual data are 36.09 and 44.82 respectively. In addition, the adjusted R^2 for the actual and contractual were 0.432 and 0.488 respectively while for that of the developed model the R^2 values are 0.445 and 0.499 respectively. The result implies the developed model was a better fit for the data set. The developed models were validated by using two standard error measures of RMSE and MAPE which were found to be 84.46 days and 8.49% for actual data and 65.58 days and 1.03% for contractual data respectively which implies the model is almost accurate forecasting for both contractual and actual project data.

The general level of time performance of building projects based on its cost is expressed based on the value of variable

K =304.12 for actual project data and

K =156.02 for contractual project data

Which shows general level of time performance per one million of Ethiopian birr.

The effect of project size on time performance of the project is expressed by the variable
B=0.280 for actual project data and
B= 0.272 for contractual project data
Which indicates how the time performance was affected by project size as measured by its cost.

- Recommendation

The developed model will be used by consultant and client during feasibility study specially in planning and tendering stages based on cost to practically predict project duration. The contractors assigned in the construction of the buildings shall use the formula to check the duration set by their clients are reasonable or not.

The study was limited to analyzing only the effect of cost on construction duration in the context of building projects in Addis Ababa, providing all other variables constant. For future studies, best fit model shall be developed by using other building describing variables such as gross floor area or building volume, number of residences, shape of building, number of stories and others.

It is recommended to develop similar models by categorizing buildings to develop a comprehensive model for different applications such as public, commercial, residential, real state, mixed use buildings then the more accurate and precise model will be generated.

This research location is limited in Addis Ababa other researches can be done by covering different region of Ethiopia separately or together.

It is advisable to continuously update the model with more project records to refine the model and improve the predictive ability since cost of construction materials and equipment varies time to time.

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