Factors of Construction Time: Construction Cost vs. Gross Floor Area

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Abstract

Studies indicate that there is a relationship between project cost and construction time for different construction markets. The purpose of this study was to validate the time-cost relationship model developed by Bromilow et al. (1980) in context with commercial, residential, and industrial construction projects in India. The model was extended to include the magnitude of the projects in terms of gross floor area and construction types to determine whether these variables also have an effect on project duration. Data related to 99 construction projects from all over India was obtained for the study. SPSS® program was used for analysis of the data. The statistical procedure used for the analysis was General Linear Model. The results show a statistically significant relationship between construction time and magnitude of the project, measured by gross floor area, at the level of significance (*p*-value) of < 0.0001. This variable, when introduced in the model, presumably acts as a proxy for actual construction cost. Construction type did not have a statistically significant relationship with construction time. A prediction model of construction time has been developed based on the results of the study. This model will be useful to constructors who work at an international level.

Keywords: Construction Time, Construction Cost, Construction Type, Gross Floor Area, Indian Construction Industry

1. Introduction

1.1 Construction Time and Construction Cost

Time and cost have been typically used as important criteria for determining project performance globally. Project cost has been identified as a correlate of construction time in many regions of the world (Bromilow et al., 1980; Choudhury & Rajan, 2008). In the construction industry, contractors usually use previous experiences to estimate the project duration and cost of a new project. In general, the more time it takes to complete an activity, the more human resources have to be engaged for the task, resulting in a higher project cost.

A relationship between completed construction cost and the time taken to complete a construction project was first mathematically established by Bromilow et al. (1980). For the

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updated model, the authors analyzed the time-cost data for a total of 419 building projects in Australia. The equation describing the mean construction time as a function of project cost was found to be:

$$T = K*C^B \quad (1)$$

Where

T = duration of construction period from the date of possession of site to substantial completion, in working days

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

K = a constant indicating the general level of time performance per million Australian dollar

B = a constant describing how the time performance is affected by the size of the construction project measured by its cost.

The model indicates that the duration of project time of a construction project is basically a function of its total cost. It provided a basis for all parties concerned with the construction process to establish a fairly accurate probable duration of a project in days, given the estimated cost of the project. The authors also analyzed the overruns on cost and time that provided a measure on the accuracy of the industry's time and cost prediction.

The model also indicates that relationship between duration of a construction project and time required to complete it is non-linear. In order to perform data analysis using a linear model, the variables need to be transformed into their natural logarithms.

Several other studies have been performed around the world to make similar predictions for either a specific sector of construction or construction industries, in general. Ireland (1985) replicated the study to predict construction time for high-rise buildings in Australia; Kaka & Price (1991) conducted a similar survey both for buildings and road works in the United Kingdom; Chan (1999) investigated the effect of construction cost on time with particular reference to Hong Kong; and Choudhury & Rajan (2008) conducted a study on residential construction projects in Texas. Hoffman et al. (2007) used Bromilow et al.'s (1980) time-cost model to analyze data collected for 856 facility projects. They, however, included certain other variables such as project location, building type, and delivery method in the model. All these studies found that the mathematical model developed by Bromilow et al. (1980) holds good for prediction of construction time when the cost of construction is known.

1.2 Construction Time and Gross Floor Area

Some studies suggest that building size is a better predictor of construction time performance than project cost. One of the first proponents of using building size as a predictor of construction time is Walker (1995). He suggests including gross floor area

(which is measure of building size or magnitude) as an independent variable in the model to predict construction time performance.

Love et al.'s (2005) study takes a similar view. They argue that construction cost, when decomposed, consists primarily of labor and material costs. They argue that while labor cost is a function of time, material cost of a building is a function of gross floor area. The speed of construction, they argue, increases with an increase in the overall quantity of materials used. Therefore, the authors conclude that construction cost is not a "good" predictor of construction time performance. Instead, they advocate an importance on floor area as a viable alternative.

Given these considerations, gross floor area seems to be a promising factor for forecasting construction time of building projects. It may be worthwhile to find out whether this particular variable is a more reliable predictor of project completion time than cost.

1.3 Construction Time and Construction Sector

Most constructors concentrate their works on a specific sector of the industry. All these sectors or divisions are usually supported by separate material and equipment suppliers, producers of components, and sub-contractors. The sectors or types are generally divided into four categories: (1) Commercial, (2) Infrastructure and heavy highway, (3) Industrial, and (4) Residential.

Both construction time and cost may vary by the sector to which a construction project belongs. In order to find out whether construction time is related to this variable, data related to three different construction sectors (commercial, industrial, and residential) were collected for analysis in this study.

1.4 Hypothesis

From a review of literature, it was assumed that the actual completion time of construction projects in India is correlated to at least three different factors. It was hypothesized that the actual completion time of construction projects in India is affected by (1) actual construction cost, (2) gross floor area of construction, and (3) the type of construction project.

2. Methodology

2.1 Data Collection Procedure and Sample Size

Data for 99 construction projects were obtained from a database of construction projects maintained by the Indian Construction Industry. It was collected in early 2010. The projects consisted of 33 commercial buildings, 33 industrial buildings, and 33 residential apartment complexes. All the projects were completed within last five years.

2.2 Data Collection Procedure and Sample Size

Actual Construction Time (TIME): It is the actual time measured for the completion of a construction project. It was measured in months. This variable was labeled as LNTIME after being transformed into its natural logarithm.

Actual Project Cost (COST): It is the total cost of construction works of a construction project. It was measured in US Dollars. This variable was labeled as LNCOST after being transformed into its natural logarithm.

Gross Floor Area (GFA): It is the gross constructed area of a construction project. It was measured in square feet. This variable was labeled as LNGFA after being transformed into its natural logarithm.

Sector of Construction (TYPE): It is the type of construction project. This was a class variable consisting of three categories, namely (1) Commercial Construction (COMMERCE), (3) Industrial Construction (INDUSTRY), and (3) Residential Construction (RESIDENT). Two dummy variables were created from this class variable: (1) Commercial Construction (COM) and (2) Industrial Construction (IND).These variables were labeled as LNCOM and LNIND after being transformed into its natural logarithms. Table 1 shows the process of creating the dummy variables and assigning values to them.

Table 1: Dummy Variables for TYPE

TYPE	LNCOM	LIND
COMMERCE	1	0
INDUSTRY	0	1
RESIDENT	0	0

3. Results

3.1 Analysis

The time-cost relationship model developed by Bromilow et al. (1980) defines only the relationship between construction time and cost. Since the present study hypothesizes a relationship to exist also between (1) construction time and gross floor area and (2) construction time and construction cost, the model had to be modified. Following model encompasses both the variables that may have an effect on construction time performance:

$$TIME = K*COST^{B1}*GFA^{B2}*COMMERCE^{B3}*INDUSTRY^{B4} \quad (2)$$

A stepwise linear regression analysis was used to perform the first step of analysis (see eqn. 3). It is a semi-automated process of building a model by successively adding or removing variables based on the *t*-statistics of their estimated coefficients. Therefore, the variables had to be transformed into their natural logarithms.

$$LNTIME = LNK + \beta_1 LNCOST + \beta_2 LNGFA + \beta_3 LNCOM + \beta_4 LNIND + \varepsilon \quad (3)$$

Where LNK = natural logarithm of K; β_1, β_2 = regression coefficients; and ε = error term.

The results show that only independent variable retained by the model was LNGFA. The other variables were significant at the level of 0.5 and were excluded. The results are shown in Table 2.

Table 2: Stepwise Linear Regression Analysis for LNTIME

Variable Retained	Intercept (LNK)	Regression Coefficient	*t*	*p*<|*t*|	Critical Value of |*t*|
Intercept	-1.2 03		-4.378	<0.0001	1.96
LNGFA		0.367	15.568	<0.0001	
F-value of the Model = 242.354	*p*>Model *F*=<0.0001			Model R^2 = 0.714 Adjusted model R^2 = 0.711	

3.2 Interpretations

The *F*-value of the model used for multiple regression analysis was found to be statistically significant at less than the 0.0001 level. This provides evidence that a relationship exists between construction time and at least one of the independent variables used in the model. The results, however, indicate only gross floor area is correlated to construction time at a very high level of significance with a *p*-value of less than 0.0001. None of the other variables, including construction cost, were found to be significant at level of significance of 0.05; hence, they were automatically excluded by the statistical package from the model.

An important aspect of a statistical procedure that derives model from empirical data is to indicate how well the model predicts results. A widely used measure the predictive efficacy of a model is its coefficient of determination, or R^2 value. If there is a perfect relation between the dependent and independent variables, R^2 is 1. In case of no relationship between the dependent and independent variables, R^2 is 0. Predictive efficacy of this particular model was found to be moderately high with an R^2 of 0.714, and an adjusted R^2 of 0.711. It means that at least 71 percent of the variances in construction time of educational projects are explained by gross floor area alone.

Based on the findings, research hypotheses indicating relationships between (1) actual completion time and cost of construction projects and (2) actual completion time and types of construction projects in India had to be rejected. However, the other hypothesis indicating a relationship between actual completion time and gross floor area of building projects in India could not to be rejected.

The prediction model for construction time of buildings in India was developed using results of the analysis. Bromilow et al.'s (1980) model was modified by replacing construction cost by gross floor area. The value of LNK was required to be transformed to K, using an exponential function [exp(LNK)], for expressing the model in its original form (Equation 4). The value was found to be 0.3. The model may be expressed as follows:

$$TIME = 0.3*GFA^{0.367} \quad (4)$$

This model can be used to predict the construction time for a building project in India when the gross floor area in known. For example, if the gross area of a construction project is, say 50,000 sft., the predicted construction time for the project would be about 16 months.

4. Conclusion

The results of the statistical analysis indicate that for a construction project in India, an increase in gross floor area results in an increase in total construction time. They also indicate that construction cost does not have to be included in the prediction model when gross floor area is available. In other words, this variable also acts as a proxy for construction cost. It can, thus, be assumed that gross floor area is a better predictor of construction time for construction projects in India. The results also did not indicate any effect of construction type on actual construction time of the projects.

The model will be useful for students of construction science, taking courses in construction project scheduling. It will also be useful for all parties associated with the construction industry to predict the mean time required for the delivery of an educational project. It provides an alternative and logical method for estimating construction time, both by bidders and clients, to supplement the prevailing practice of estimation predominantly on individual experience. The predict construction time for projects in other sectors.

This study has been conducted using data for construction of building projects in India. The construction industry can benefit from the results of the study by applying the model in predicting construction time for similar projects. Such models may be developed by collecting historical data either from the owners or the constructors. However, the model documented in this study applies only for construction projects in India and cannot be generalized beyond the sample size.

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