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EFFECT OF GROSS FLOOR AREA ON CONSTRUCTION TIME

IFTE CHOUDHURY

Dept of Construction Science, Texas A&M University, College Station, USA

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 the context of 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 were obtained. The SPSS® program and the General Linear Model were used for analysis. 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). 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 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:

$$T = K*C^{B} \qquad (1)$$

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 dollars; and ^{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 also indicates that relationship between the 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) is valid 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 a 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 deconstructed, consists primarily of labor and material costs. They maintain that while labor cost is a function of time, the 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 the importance of floor area as a viable alternative.

A recent study by Shanmugapriya & Subramanian (2013) provides an interesting insight related to relationship between construction time overrun and increase of floor area "at owner's request" (p. 738). After an extensive study on the factors of time overrun in Indian construction industry, the results indicate that, for almost all types of construction projects, floor area is a statistically-significant predictor of construction time.

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. In order to test whether gross floor area is a probable predictor of actual construction cost, Bromilow et al.'s (1980) model has been extended to include this variable in the present study.

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.

1.4 Hypotheses

Assuming that the determinants of construction time are actual construction cost, gross floor area of a building, and the type of construction, it is 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 actual completion time.

2 METHODOLOGY

2.1 Data Collection Procedure and Sample Size

Data for 99 construction projects were obtained from the database of construction companies in different regions of India that completed these projects. A questionnaire was developed to collect user satisfaction data on (1) type of project, (2) actual construction time of the project, (3) actual construction cost of the project, and (3) total built-up area. Data collection was done through telephonic interviews. 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 the last five years.

2.2 Variables and Their Operationalization

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

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

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

Sector of Construction (TYPE): This is the type of construction project. It was a class variable consisting of three categories, namely (1) Commercial Construction (COMMERCE), (2) 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 labelled as LNCOM and LNIND after being transformed into their 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 ANALYSIS, RESULTS, & INTERPRETATIONS

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. The 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 Eq. 3). The variables had to be transformed into their natural logarithms to perform the analysis, as follows:

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

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

The results show that the 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		

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.

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 sub-hypothesis indicating a relationship between actual completion time and gross floor area of building projects in India could not be rejected.

The prediction model for construction time of buildings in India was developed using results of the analysis. It may be expressed as follows:

$$\text{TIME} = 0.3 * \text{GFA}^{0.367} \tag{4}$$

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 sq. ft., the predicted construction time for the project would be about 16 months.

4 CONCLUSIONS

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. This simplified model helps to better understand the underlying mechanism behind construction time.

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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