AC 2009-617: TIME-COST RELATIONSHIP FOR INFRASTRUCTURE PROJECTS IN INDIA

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Time-Cost Relationship for Infrastructure Projects in India

Abstract

Studies indicate that there is a relationship between project cost and construction time for different construction markets and construction sectors. The purpose of this study is to validate the time-cost relationship model developed by Bromilow et al.[1] in context with infrastructure (i.e. bridges and roads/ highways) projects in India. The model was extended to include change orders to determine whether this variable also has an effect on project duration. Data related to 50 infrastructure projects in India completed within last five years was obtained for the study. SPSS® program was used for analysis of the data. The statistical technique used for the analysis was a multiple linear regression. The results indicate that Bromilow et al.'s[1] model holds good for the Indian Construction Industry at the level of significance (*p*-value) of < 0.0001. The results indicate that there is a statistically significant relationship between construction time of infrastructure projects and their actual construction cost and number of change orders.

Key words: Change Orders, Construction time, Construction Cost, Infrastructure Construction, Indian Construction Industry

Introduction

Prediction of construction time at planning and bid preparation stages is necessary for including realistic project duration in the bid package. It represents a problem of continual concern and interest to both researchers and contractors. It is also important for the studies related to estimating, scheduling, and management of construction works taught both at the graduate and undergraduate levels in the schools of construction. A number of studies have been conducted on time-cost relationship for various construction sectors around the world. This study takes into infrastructure construction projects in India; a time-cost relationship model developed by Bromilow et al.[1] and validated by few other researchers has been used to verify whether such a relationship holds good for this sector of the construction industry in India. Infrastructure in India generally means highways and utilities pipelines. The model was extended to include the effect of change orders also on construction time of such projects. It is hypothesized that the total construction time for infrastructure construction India is (1) positively correlated with the total construction cost of a project and (2) affected by the number of change orders issued during the construction period.

Empirical model for prediction of construction time

A relationship between completed construction cost and the time taken to complete a construction project was first mathematically established by Bromilow et al.[1] 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:

$$T = K*C^B \tag{1}$$

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.

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[2] replicated the study to predict construction time for high-rise buildings in Australia; Kaka & Price[3] conducted a similar survey both for buildings and road works in the United Kingdom; Kumaraswamy & Chan[4] investigated the effect of construction cost on time with particular reference to Hong Kong; Chan[5] did a similar research for Malaysian construction industry; and Choudhury et al. [6] (2002) conducted a study on health sector construction projects in Bangladesh.

Hoffman et al.[2] used Bromilow et al.'s[1] 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.[1] holds good for prediction of construction time if the cost of construction is known. This present study is an effort to validate the same model for Indian construction industry, particularly with reference to the commercial and industrial sectors.

Change orders during construction

Change orders are very common in construction projects; Indian construction industry is no exception. Even the best prepared plans are subject to changes during construction phase and the mediocre and worst laid plans often end up in lawsuits since they may cause serious productivity losses[8, 9]. They may lead to budgetary and schedule changes. Budgetary changes are principally measured by the amount of work adjusted and the data related to budgetary changes is generally objective and reliable. However schedule changes can be complicated, as time extensions or reductions are not necessarily proportional to budgetary changes[10]. In order to ascertain the impact of this important variable on construction time, it is essential to include in the time-cost relationship model. The original model was thereby extended to include the effect of change orders on construction time.

Research Objectives

The primary objectives of the study were:

- To validate the time-cost relationship developed by Bromilow et al.[1] with respect to infrastructure construction projects in India

- To find out whether change orders during construction period affect total construction time for infrastructure construction projects in India

Hypothesis

It is hypothesized that the total construction time for infrastructure construction India is (1) positively correlated with the total construction cost of a project and (2) affected by the number of change orders issued during the construction period.

Research methods

Data collection

Sixty six construction companies from infrastructure construction sector in India were randomly selected from an existing database. A questionnaire was prepared to collect data related to actual construction time, actual construction cost, and total number of change orders during the construction period. It was sent electronically to all the companies selected. Data was collected for 50 infrastructure projects from 50 companies. The response rate was 75.76 per cent.

Variables

Construction Time (TIME): It is the actual time for completion of an infrastructure project measured in months. For the purpose of the statistical analysis, the value of the variable was transformed into its natural logarithm.

Construction Cost (COST): It is the total cost of the construction of an infrastructure project measured in millions of Indian Rupees (1 US Dollar = 41 Indian Rupees). For the purpose of the statistical analysis, the value of the variable was transformed into its natural logarithm.

Number of Change Orders (CO): It is the number of change orders associated with an infrastructure project. For the purpose of statistical analysis it was transformed in to its natural logarithm.

Category (CAT): It is a dummy variable indicating the category of an infrastructure project. The study identified two categories of infrastructure construction: (1) highways and (2) utilities pipelines. For the convenience of statistical analysis, it was redefined as its natural logarithm. A value of ‘1’ was assigned to the natural logarithm of the variable for highways, other wise the value was ‘0.’

Results

The time-cost relationship model developed by Bromilow et al.[1] was extended to include three additional explanatory variables: change order, category, and procurement method. The model was modified as follows:

$$TIME = K*COST^{\beta 1}*CO^{\beta 2}*CAT^{\beta 3} \quad (2)$$

where

TIME = duration of construction time months, COST = completed cost of the project in million Indian Rupees, K = a constant indicating the general level of time performance for a project worth one million Indian Rupees, CO = the number of change orders, CAT = category of infrastructure construction project, β_1 = a constant indicating how the time performance is affected by the size of the construction project measured by its cost, β_2 = a constant indicating how the time performance is affected by a variation in number of change orders, and β_3 = a constant indicating how the time performance is affected by a variation in category.

A multiple linear regression was used to analyze the data. For statistical analysis, Bromilow et al.'s [1] model was rewritten in the natural logarithmic form as follows:

$$LnTIME = LnK + \beta_1 LnCOST + \beta_2 LnCO + \beta_3 LnCAT \quad (3)$$

where

LnTIME = natural logarithm of time, LnK = natural logarithm of K, LnCOST = natural logarithm of cost, LnCO = natural logarithm of the value of the number of change orders, LnCAT = natural logarithm of the value of category, β_1 = regression coefficient of LnCOST, β_2 = regression coefficient of LnCO, and β_3 = regression coefficient of LnCAT.

The results of the analysis are shown in Table 2.

Table 2: Results of multiple regression analysis

Variable	Intercept (LnK)	Regression Coefficients	t-value	Significance (p-value)
Intercept	1.478		3.788	<0.0001
LnCOST		0.276	4.906	<0.0001
LnCO		0.270	0.172	0.8640
LnCAT		-0.470	-0.305	0.7620
F-value of the model = 27.69 (p>0.0001)	R^2 = 0.37	Adjusted R^2 = 0.35		

The results indicated that a statistically significant relationship existed between LnTIME and LnCOST. No relationship was found between LnTIME and the LnCO and LnCAT at the 0.05 level.

The model, which is derived from empirical data, needs to be checked for its predicative efficacy. A widely used measure for checking the predicative efficacy of a model is its coefficient of determination, or R^2 value. Perfect relation is said to exist between the dependent and independent variables, if R^2 is 1 and no relationship exists between the dependent and independent variables, if R^2 is 0. Predictive efficacy of this particular model was not found to be high with an R^2 of 0.37, and an adjusted R^2 of 0.35. The model explains only 35 percent of the variability of construction time of an infrastructure project in India. This is because the other two independent variables included in the model do not have any effect on the dependent variable. Moreover, such values are usually considered to be satisfactory related to empirical studies in social sciences[11]. The F-value of the model was found to be statistically significant at less than the 0.0001 level. It indicates that the model as a whole accounts quite well for the behavior of construction cost as a predictor variable.

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 2). It was found to be 4.384. By excluding the variables that did not have a statistically significant relationship with construction time, the model can be expressed as follows:

$$TIME = 4.384 * COST^{0.276} \quad (4)$$

Conclusions

The results of the statistical analyses indicate that time-cost relationship model developed by Bromilow et al.[1] holds good infrastructure construction projects in India. Higher the actual construction cost, more is the duration of construction. Even though the model as the model as a whole provides only mild a support to the research hypothesis, but shows that more than 35 per cent of the variance in construction time is explained by construction cost of the infrastructure projects. However, no attempt should be made to generalize this finding because of the small sample size.

Number of change orders and category of infrastructure do not have any impact on actual construction time. This is very surprising in the Indian construction scenario, as it takes a long time to process a change order due to tedious bureaucratic procedures. The issue of change orders needs to be investigated in further details with reference to Indian Construction Industry.

The study was limited to investigate only the effect of cost on construction time and change orders in the context of infrastructure projects in India, keeping all other variables constant. For future studies, it will be useful to include other variables such as productivity of the workforce, impact of client decision-making, management attributes, issues related to land acquisition, soil condition, and project environment, and analyze their effect on total construction time.

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