EFFECTS OF CONSTRUCTION COST AND CHANGE ORDERS ON CONSTRUCTION TIME FOR INDUSTRIAL AND COMMERCIAL PROJECTS IN INDIA

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Abstract

Studies indicate that there is a relationship between project cost and construction time within construction projects. The purpose of this study is to validate a time-cost relationship model developed by Bromilow et al. (1980) with reference to both commercial and industrial construction projects in India. The model was extended to include change orders and construction procurement methods to determine whether these variables would also have an effect on project duration. Data related to 20 industrial and 27 commercial projects completed in India within last five years was obtained for the study. SPSS® software was the primary data analysis tool. The statistical technique used for the analysis was a multiple linear regression. The results indicate that Bromilow et al.'s (1980) model holds good for the Indian construction industry at the level of significance (p-value) of < 0.0001. The results also indicate that there is a statistically significant relationship between construction time and actual construction cost as well as between construction time and number of change orders, both in commercial and industrial sectors. Furthermore, the results indicate that, in India, the time taken for construction of commercial projects is significantly higher than that for industrial projects.

Keywords: Change Orders; Construction Time; Construction Cost; Indian Construction Industry; Procurement Method.

Introduction

Accurate prediction of construction time at planning and bid preparation stages is necessary for including realistic project duration information 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 at the graduate and undergraduate levels in schools of construction. A number of studies have already been conducted with regards to time-cost relationships for various construction sectors around the world. This study takes into consideration the commercial and industrial construction industries in India. A time-cost relationship model, developed by Bromilow et al. (1980) and validated by previous researchers, has been used to verify whether such a relationship holds good for these sectors in the Indian construction industry. The model was also extended to include the effect of change orders on construction time. It is hypothesized that the total construction time for both commercial and industrial projects in 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. (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:

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

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 dollars

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

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 (1986) 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; Kumaraswamy & Chan (1995) investigated the effect of construction cost on time with particular reference to Hong Kong; Chan (1999) did a similar research for the Malaysian construction industry; and Choudhury et al. (2002) conducted a study on health sector construction projects in Bangladesh.

Hoffman et al. (2007) used Bromilow's time-cost model to analyze data collected for 856 facility projects. However, they 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 if the cost of construction is known. This present study is an effort to validate the same model for the Indian construction industry, particularly with reference to commercial and industrial sectors.

Change orders during construction

Change orders are very common in construction projects, the Indian construction industry is no exception. Even the best prepared plans are subject to changes during the construction phase. Mediocre and badly prepared plans often produce construction projects that end up in lawsuits since they may cause serious productivity losses (Thomas, 1995; Hanna & Gunduz, 2004). Change orders 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 (Chao et al., 2004). In order to ascertain the impact of this important variable on construction time, it is essential to include it in the time-cost relationship model. The original model was thereby extended to include the effect of change orders on construction time.

Procurement method

Construction procurement is the process of obtaining services and supplies for efficient and timely delivery of the end product. The major procurement methods include (1) Design-Bid-Build, (2) Design-Build, and (3) Construction Management at Risk. Even though it is advisable to select a procurement strategy that suits the nature of a project, Design-Bid-Build is the method of choice in India. Studies indicate that project performance is affected by procurement method (Choudhury & Pitkar, 2007; Ling et al., 2004; Chan et al., 2002), therefore, the impact of this variable on construction time was ascertained by including it in the time-cost relationship model.

Research methods

Research hypothesis:

Total construction time for both commercial and industrial construction projects in India is (1) positively correlated with the total construction cost of a project and (2) the number of change orders issued during the construction period.

Research Objectives:

- To validate the time-cost relationship developed by Bromilow et al. (1980) with respect to commercial construction projects in India
- To validate the time-cost relationship developed by Bromilow et al. (1980) with respect to industrial construction projects in India
- To find out whether change orders during construction period affect total construction time both for commercial and industrial projects in India
- To find out whether methods of procurement affect total construction time both for commercial and industrial projects in India

Data collection

Seventy construction companies, both from commercial and industrial sectors 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. The questionnaire was sent electronically to all the companies selected. Data was collected for 27 commercial projects and 20 industrial projects; 47 projects overall constructed during the last five years. The response rate was 67.14 percent.

Variables

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

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

Number of Change Orders (CO): is the number of change orders associated with a project. For the purpose of statistical analysis it was transformed into its natural logarithm.

Category (CAT): It is a dummy variable indicating the category of a construction project. 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 commercial projects, otherwise the value was set to '0.'

Procurement method: This is the method used for construction and delivery of the projects. Two dummy variables, Construction Management at Risk (CMR) and Design-Bid-Build (DBB) were created from this category variable. For the convenience of statistical analysis, they were redefined in terms of their natural logarithm. A value of '1' was assigned to the natural logarithm of the variable for CMR, otherwise the value was set to '0.' Similarly, a value of '1' was assigned to the natural logarithm of the variable for DBB, otherwise the value was set to '0.'

Research results

The time-cost relationship model developed by Bromilow et al. (1980) was extended to include three additional explanatory variables: change order, category, and procurement method. The model was modified as follows:

$$TIME = K*COST^{\beta 1}*CO^{\beta 2}*CAT^{\beta 3}*CMR^{\beta 4}*DBB^{\beta 5} \quad (2)$$

where

TIME = duration of construction time in 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 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, β_3 = a constant indicating how the time performance is affected by a variation in category, β_4 = a constant indicating how the time performance is affected when the procurement method is CMR, and β_5 = a constant indicating how the time performance is affected when the procurement method is DBB.

A multiple linear regression was used to analyze the data. For statistical analysis, Bromilow et al.'s (1980) model was rewritten in the natural logarithmic form as follows:

$$LnTIME = LnK + \beta_1 LnCOST + \beta_2 LnCO + \beta_3 LnCAT + \beta_4 LnCCMR + \beta_5 LnDBB \quad (3)$$

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, LnCMR = natural logarithm of the value of CMR, LnDBB = natural logarithm of the value of DBB, β_1 = regression coefficient of LnCOST, β_2 = regression coefficient of LnCO, β_3 = regression coefficient of LnCAT, β_4 = regression coefficient of LnCMR, and β_5 = regression coefficient of LnDBB.

The results of the analysis are shown in Table 2.

Table 1. Results of multiple regression analysis

Variable	Intercept (LnK)	Regression Coefficients	t-value	Significance (p-value)
Intercept	1.154		2.321	0.0250
LnCOST		0.216	3.908	<0.0001
LnCO		0.265	4.676	<0.0001
LnCAT		0.248	2.853	0.0070
LnCMR		-0.091	-0.792	0.433
LnDBB		-0.073	-0.614	0.542
F-value of the model = 11.99 (p>0.0001)	R^2 = 0.59	Adjusted R^2 = 0.54		

The results indicated that a statistically significant relationship exists between LnTIME and LnCOST, LnCO, and LnCAT. No relationship was found between LnTIME and the dummy variables (LnCMR and LnDBB) representing procurement method, at the 0.05 level.

The findings provide evidence that time taken for construction for both industrial and commercial projects is positively correlated with actual construction cost and number of change orders.

The relationship between LnTIME and LnCAT suggests a statistically significant difference in actual construction time between commercial and industrial sectors. Least Significant Difference (LSD) option of General Linear Model was used to find out the direction of the difference in actual construction time. The results are shown in Table 2.

Table 2. Pairwise comparison

Category	LnTIME	Mean Difference	Significance (p-value)
Commercial	3.366	0.248	0.007
Industrial	3.119	-0.248	

The results show that actual construction time for commercial projects in India is higher than that for industrial projects. The difference is statistically significant at the 0.007 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 found to be moderately high with an R^2 of 0.59 and an adjusted R^2 of 0.54. The F-value of the model was found to be 11.99 which is statistically significant at less than 0.0001 level. It indicates that the model as a whole accounts quite well for the behavior of the predictor variables.

Discussion and conclusions

Key lessons learned

The results of the statistical analyses indicate that the time-cost relationship model developed by Bromilow et al. (1980) holds good for both commercial and industrial construction projects in India. Higher actual construction costs result in longer duration of construction.

Construction time for commercial projects, however, is found to be significantly higher than that for industrial projects. This can be attributed to the fact that assembly and installation of components for industrial projects can be done quicker than with those required for commercial projects.

Number of change orders has an impact on actual construction time for the type of project. A higher number of change orders results in a longer duration of construction. This is not very surprising in an Indian construction scenario, as it takes a long time to process a change order due to tedious bureaucratic procedures. This is more apparent in industrial construction projects where most of the clients are governmental agencies or public sector companies.

Procurement method was not found to have any effect on construction time. This is more or less in line with the findings of other studies regarding the impact of delivery systems on project duration (Choudhury & Pitkar, 2007; El Wardani et al., 2006). This issue needs to be investigated in further detail with reference to the Indian construction industry.

This study was limited to investigating the effects of project cost and change orders on construction time in the context of commercial and industrial projects in India, keeping all other variables constant. For future studies, it would be useful to analyze the effect of other variables on the total construction time. These variables could include: productivity of the workforce, impact of client decision-making, management attributes, construction materials and project environment.

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Author's Biography

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