AC 2007-2479: THE EFFECT OF SUB-CONTRACTING ON CONSTRUCTION TIME FOR COMMERCIAL PROJECTS IN CHENNAI, INDIA

I. Choudhury, Texas A&M University

IFTE CHOUDHURY Ifte Choudhury is an Associate Professor in the Department of Construction Science at Texas A&M University. Dr. Choudhury has extensive experience as a consulting architect working on projects funded by the World Bank. His areas of emphasis include housing, alternative technology, issues related to international construction, and construction education. He is also a Fulbright scholar.

Tharuna Khilathi, Texas A&M University

THARUNA KHILATHI Tharuna Khilathi is an architect and a constructor by profession. She obtained a Master of Science in Construction Management from Texas A&M University. Ms. Khilathi has extensive experience as a professional architect working on commercial projects in India. Her areas of interest include architectural design and project controls.

The Effect of Sub-contracting on Construction Time for Commercial Projects in Chennai, India

Abstract

The purpose of this study was to examine the factors that effect actual construction time in the context of commercial projects in Chennai, India. One of the factors of particular interest was the extent of sub-contracting in construction projects. The data for the study was obtained from a few leading design and construction management companies in Chennai, India. The sample size consisted of 53 commercial construction projects scattered all over the region. The effect of sub-contracting on construction time was analyzed in conjunction with other known variables of time overrun, such as actual project cost and number of change orders. The results indicated that the effect of use of sub-contractors on construction time was statistically significant even in the presence of actual project cost and change order variables. It was concluded that the extent of sub-contracting could be included in prediction models used for finding out actual construction time of commercial projects, at least in this particular region of India. Based on these findings, a prediction model for construction time for such projects was developed.

Keywords: Construction time, Construction Cost, Commercial projects, Indian Construction Industry, International Construction, Sub-contractors.

Introduction

Time and cost are two major concerns in construction projects. In the construction industry, contractors usually use previous experiences to estimate the project duration and cost of a new project. In general, the more resources assigned to an activity, the less time it will take to complete the activity, but the cost is usually higher. This trade-off between time and cost gives construction planners both challenges and opportunities to work out the best construction plan that optimizes time and cost to complete a project.

The fundamental focus of project management has been to deliver projects on time, on budget and meet specifications. However, many major projects still fail to meet these targets, especially on cost and schedule. Owners and shareholders have always been concerned with fast-tracking projects, cutting costs and building safer buildings. The means of achieving these goals are not very clear to the industry. We occasionally read about successful projects that meet all of these goals; nonetheless, stories about failed projects, cost and time overruns, and drawn out court cases continue to dominate the headlines.

Literature indicates that investment in global construction is about 10% of the global economy. About 70% of this investment is in USA, Europe, and Japan, and 30% is in the rest of the world. Keeping such a magnitude of investment in mind, different governments have undertaken initiatives to improve the overall performances of the construction projects and the construction industry. Most of the studies related to improved performance in the construction industry have been done in the context of the developed countries; the applicability of the findings of such studies in the developing countries such as India is yet to be explored. Although the Indian construction industry has gained far more importance in recent times because of opening up of Indian markets and the arrival of mega projects for infrastructure development, the performance of Indian construction projects has, however, not been very encouraging. The construction sector in India accounts for nearly 12% of its GDP (Iyer & Jha, 2006) and is emerging as one of the key growth segments in the economy. The sector's contribution is likely to increase even more in the coming years.

This paper attempts to examine the relationship between actual construction time and construction related to commercial projects in Chennai, India. Focusing on project management issues, a projects success is measured in terms of its performance on schedule, cost, and quality. Schedule and cost are still widely used as performance measures of a project (Iyer & Jha, 2006). Hence, the discussion on this paper is limited to schedule performance of commercial construction projects. Apart from cost, there are many other factors that affect construction time. Magnitude of subcontracting is one such factor that definitely has an impact on productivity, and thereby, on construction time. Some other factors that may affect time performance include design changes and level of construction supervision. Therefore, apart from cost, the effects of these variables on construction time have also been examined in this study.

Review of literature

Indian Construction Industry

The construction industry is a vital component of the Indian economy, generating total revenue of $ 30.7 billion in 2005, with a compound annual growth rate (CAGR) of 7.2% for the five-year period spanning 2001-2005 (Data monitor, 2006). The challenging economic conditions and the low construction productivity have construction owners and managers looking for ways to reduce cost (Picard, 2005). However, many construction projects still face problems of time overruns due to poor project planning, inaccurate project schedules, and overall project management.

The Indian construction and engineering industry is developing quickly and consistently year-on-year with a growth rate of 96.7% since the beginning of the decade. This industry behavior is predicted to continue until the end of the decade. The Indian industry value is generated through two segments: commercial construction and infra-structure development. Among these segments, infra-structure development is by far the more lucrative, generating $26.4 billion of revenue in 2005, equivalent to 85.8% of the total industry's value. The non-residential segment generates the remaining 14.2% of the industry's value.

The Indian construction industry is characterized by the predominance of migratory and unskilled labor. A majority of the Indian construction labor force are self employed, and usually farmers from rural areas. They are often recruited through friends or relatives (typically the foremen), and are low skilled, earn low wages, and are hence less productive. Therefore, there is need to expand the training and skill certification programs, both in terms of content as well as geographical reach. The contracting workforce is largely informal and untrained, consisting of many small-sized firms with low skill levels. There are only a few Indian contractors well-organized and capable enough to undertake significant national capital asset projects.

Impact of subcontracting on construction projects

Subcontractors produce a large portion of construction work under the supervision of general contractors. The contribution of subcontractors to the total construction process can account for as much as 90 per cent of the total value of a construction project. In the construction process efficient subcontractor operation is expected to be beneficial to all parties involved, including the owner, general contractor, and the subcontractors themselves. Subcontractors bear responsibility for much of the productivity achieved on the construction site, particularly in areas such as labor relations, supervision, material delivery, prefabrication, standardization, worker training, quality control, and equipment maintenance and utilization (David & Chotibhongs, 2005). Though subcontracting has significantly affected site productivity, it is never included as a key factor in productivity research studies. The reason being in smaller projects either no work is subcontracted or the volume of subcontracted work is kept to a minimum; and in the research framework, subcontractors are collectively fitted into the conceptual category of the contractor (David & Chotibhongs, 2005).

Increase in construction project scale and complexity induces difficulty in project control. Suitable project organizational structure is the key element for the smooth execution of a huge construction project; it improves the efficiency of communication between different groups of project members. With an increase in the number of participants in a construction project, efficiency of communication may decrease. In India, there is a general tendency among general contractors to fragment a project into too many subcontracts in order to maximize profit. It will be interesting to examine the effect of using too many sub-contractors on project management.

Studies have shown that in order to improve subcontractor productivity, subcontractors should be familiar with modern construction/production methods. The reason being modern construction/production methods are expected to reduce the duration and cost of construction projects (David & Chotibhongs, 2005). Research has shown that site productivity can also be improved by effective quality management. There also seems to be an agreement between the parties that subcontractors' familiarity with modern management techniques and their efforts to reduce accident rates and motivate workers constitute secondary measures for improved productivity.

Due to the numerous working interfaces, complicated networks, and diversified team members of a large construction project, coordination efficiency among members of the construction team is vital to the success of construction project.

Construction cost

From previous researches and studies conducted it has been identified that cost plays a significant role on time overruns. Bromilow, et al. (1980) mathematically established a relationship between completed construction cost and the time taken to complete a construction project. 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:

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

where T = duration of construction period from the date of possession of site to substantial completion, in wording 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, and β = a constant describing how the time performance is affected by the size of the construction project measured by its cost.

This model indicated that the duration 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.

Building on the model developed by Bromilow et al. (1980), some other studies have been performed to make similar predictions for either a specific sector of construction or construction industries, in general, around the world. 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 Malaysian construction industry; and Choudhury, Khan, & Matin (2002) conducted a study on health sector construction projects in Bangladesh. All these studies found that the mathematical model presented by Bromilow et al. (1980) holds good for prediction of construction time if the cost of construction is known.

Other variables of construction time

It has been identified that the major variables leading to time overruns are inclement weather; design changes; inadequate planning as a result of inaccurate prediction of craftsmen's production output (especially in developing countries, where outputs are yet to be standardized), inaccurate prediction of equipment production rates, materials shortages, equipment shortages, skill shortages; and poor labor productivity. Also complexity of project, lack of geographical experience or lack of project type experience by contractor, and non-familiarity with local regulations can lead to delays (Kaming et al., 1997).

Moreover, construction time can also be affected due to disruption and delay caused by the project client. Kaming et al. (1997) reports that the predominant factors influencing time overruns/delays are design changes, poor labor productivity, inadequate planning and resource shortages. Besides, projects now-a-days tend to become more time-constrained, and the ability to deliver a project quickly is becoming an increasingly important element in winning a bid; and furthermore, there is an increasing emphasis on tight contracts, using prime contractorship to pass time-risk on to the contractor, frequently with heavy liquidated damages for delays.

In developing commercial projects in India, design tends to be changed during construction to attract more tenants. In many cases, these design changes can cause significant delays in reaching substantial completion of the building within the budget.

Hypothesis

This paper attempts to find out the factors that may affect the actual time of construction for commercial projects in Chennai, India using the time-cost relationship model developed by Bromilow, et al. (1980). It is hypothesized that, apart from actual construction cost, the actual construction time for such projects is also affected by:

1. Number of change orders,
2. Number of subcontractors employed in a project, and
3. The level of supervision of construction.

Research Methodology

Data collection

An instrument was prepared and mailed electronically to 23 architectural and engineering companies in Chennai, India. Data related to actual construction time, actual construction cost, change orders, number of subcontractors employed, and the level of construction supervision provided by the companies were obtained for 53 commercial construction projects in that region. The projects were designed by the relevant architectural and engineering companies and constructed using design-bid-build method. Fifteen projects had full-time supervision, 27 had part-time supervision, and 11 had no supervision provided by the AE companies,

Variables and their Operationalization

Actual construction time (TIME): It is the actual completion time of a commercial construction project. It is measured in number of months. This is the dependent variable in the study.

Actual construction cost (COST): It is an independent variable in the study. It is the total cost of the construction works of a commercial sector construction project.

Number of change orders in the project (CORDER): It is an independent variable in the study. It is the number of change orders that were issued in a project.

Number of subcontractors in a project (SUBS): It is an independent variable in the study. It is the number of subcontractors that were working on a project.

Supervision provided by the architect (SVISION): It is the level of supervision provided by an architectural/engineering company for the construction project. The levels of supervision are: (1) Full-time supervision, (2) Part-time supervision, and (3) No supervision (NSVISION). Two dummy variables, (1) Full-time supervision (FSVISION) and (2) Part-time supervision (PSVISION) were created from this category variable.

Statistical Methods

The technique used for the analysis of data was multiple linear regression analysis using stepwise method. This was done using Statistical Package for the Social Sciences (SPSS) program.

Analysis

In this study the effects of actual construction cost, sub-contracting, change orders, and level of supervision on construction time for commercial projects were analyzed by extending the time-cost relationship model (Eqn. 1) developed by Bromilow (1980). The additional explanatory variables (subcontractors, change orders, and supervision) were included and the model was modified as follows:

$$TIME = K * COST^{\beta 1} * SUBS^{\beta 2} * CORDER^{\beta 3} * FVISION^{\beta 4} * PSVISION^{\beta 5} \quad (2)$$

Where,
TIME = duration of construction time in months,
COST = completed cost of the project in 100,000 Indian Rupees,
K = a constant indicating the general level of time performance for a project worth one thousand Rupees,
CORDER = the number of change orders that were issued in a project during the construction period,
SUBS = the number of subcontractors that were working on a project,
FSVISION = full-time supervision provided by an architectural/engineering company,
PSVISION = part-time supervision provided by an architectural/engineering company,
β1 = a constant indicating how the time performance is affected by the size of the construction project measured by its cost,
β2 = a constant indicating how the time performance is affected by the number of subcontractors working on a project,
β3 = a constant indicating how the time performance is affected by the number of change orders issued in a project during the construction period,
β4 = a constant indicating how the time performance is affected by full supervision,
β5 = a constant indicating how the time performance is affected by part-time supervision provided by the architect

The model was then rewritten in the natural logarithmic form as follows as shown in equation 3 to make it linear:

$$LnTIME = Ln\ K + \beta_1\ LnCOST + \beta_2\ LnSUBS + \beta_3\ LnCORDER + \beta_4\ LnFSVISION + \beta_5\ LnTSVISION \quad (3)$$

Where;
LnTIME = natural logarithm of time,
LnK = natural logarithm of K,
LnCOST = natural logarithm of cost,
LnSUBS = natural logarithm of the value of SUBS,
LnCORDER = natural logarithm of the value of CORDER,
LnFSVISION = natural logarithm of the value of FSVISION,
LnTSVISION = natural logarithm of the value of TSVISION
B_1 = coefficient of LnCOST,
β_2 = coefficient of LnSUBS,
β_3 = coefficient of LnCORDER,
β_4 = coefficient of LnFSVISION, and
β_5 = coefficient of LnTSVISION

The results of the analysis are shown in Table 3.

Table 3

Multiple Linear Regression Analysis using stepwise method for LnTIME

Variable	Intercept	Regression Coefficient	T	*p*>|T|	Critical Value of |T|
Intercept	-5.553		-5.527	0.000	1.67
LnCOST		0.562	6.894	0.000	
LnSUBS		0.441	5.405	0.000	
Model R^2 = 0.739					
Adjusted Model R^2 = 0.729					
F-value of the Model = 70.911					
p>Model F Value = <0.0001					

The results indicate that the natural logarithm of actual completion time of the project is positively related to the natural logarithm of total project cost and the number of subcontractors working on the project at the level of significance of p<0.0001. None of the other variables had any effect on actual construction time with very low coefficient values and low significance levels.

The model was now re-written in the natural logarithmic form to include only actual project cost and the number of subcontractors as the explanatory variable and modified as follows:

$$LnTIME = Ln\ K + \beta 1\ LnCOST + \beta 2\ LnSUBS \quad (4)$$

It can also be re-written as follows, confirming to Bromilow's model (Eqn. 1):

$$TIME = K * COST^{\beta 1} * SUBS^{\beta 2} \quad (5)$$

Interpretations

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 for the predicative 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 0.739, and an adjusted R^2 of 0.729.

The results indicate that the actual completion time of the project is positively related to the total project cost at the level of significance of 0.0001. The *F* statistic of a model basically tests how well the model, as a whole, accounts for the dependent variable's behavior. The *F*-value of this particular model was found to be statistically significant at less than the 0.0001 level.

The results of the statistical analysis indicate that the construction time of a commercial construction project in Chennai, is correlated with its total construction cost and the number of subcontractors on the project. It is not affected by the number of change orders or the level of supervision provided by the Architect. It can therefore be concluded that the construction time for commercial projects in Chennai, is affected by the number of sub-contractors on a project and also sub-contracting can be included in the prediction models used for finding the actual construction time. The model, for the purpose of prediction of construction time for commercial projects in Chennai, India, may be expressed as follows:

$$TIME = 0.0039 * COST^{0.47} * SUBS^{0.65} \quad (6)$$

(The value of LnK was required to be transformed to K, using an exponential function [exp (LnK)]. The value was found to be 0.0039.)

Using the above model, it is found that for a commercial project worth 10 million rupees and having 10 subcontractors, the construction time is 34 months for the project completion; the actual construction time for a project worth 500 million rupees is predicted to be 72.5 months.

Conclusion

The results of the statistical analysis indicate that for a commercial construction project in Chennai, India, an increase in total construction cost results in an increase in total construction time. Also this study indicates that there is a significant relation between construction time and the number of subcontractors on a project. The level of supervision provided by the architect and the number of change orders does not affect the project time. The significant relationship between the construction time and the numbers of subcontractors on a project can be explained through the literature study that indicates the use of a large number of subcontractors on a project means increased complexity of both the construction of buildings and the organizational relationships. It may eventually lead to time overrun.

This is an important study which explains the factors that affect the construction time of a commercial project in India. This research provides evidence that there is not only a relationship between project cost and project time but, also a significant relationship between the number of subcontractors on a project, and its construction time. Also, this research through a review of literature gives a brief overview of important factors that affect project time. The factors identified as contributing to the construction time of a project are design changes, poor labor productivity, inadequate planning, resource shortages and subcontractors on a project. The above study will help inform readers about factors influencing the construction time of a commercial construction

This study will hopefully generate enough interest to do further research for deriving models to predict construction time for projects in other sectors. This study was limited to investigate only the effect of cost, change orders, effect of subcontractors and Architects supervisions in the context of commercial construction projects in Chennai, India. For further studies, it will be useful to include other variables such as productivity of the work force, delays in progress payments, weather conditions, etc. and analyze their effect on the total construction time. In addition this study identified a significant relationship between the construction time and the subcontractors on a project. A detailed study on this relationship can be done in the future to find why such a relationship exists.

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