AC 2012-3382: EFFECTS OF CONSTRUCTION COST AND VOLUME ON CONSTRUCTION TIME OF EDUCATIONAL PROJECTS IN TEXAS

Dr. Ifte Choudhury, Texas A&M University

Ifte Choudhury is an Associate Professor in the Department of Construction Science at Texas A&M University. 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.

A Study of the Factors of Construction Time for Educational Projects in Texas

Abstract

Studies indicate that there is a relationship between project cost and construction time for different construction markets. The purpose of this study is to validate the time-cost relationship model developed by Bromilow et al.[1] in context with educational construction projects in Texas. The model was extended to include the magnitude of the projects in terms of gross floor area and project delivery methods to determine whether these variables also have an effect on project duration. Data related to 39 educational projects was obtained for the study. SPSS® program was for analysis of the data. The statistical technique used for the analysis was stepwise linear regression. The results indicate that when gross floor area is also used an independent variable, construction cost does not have any relationship with construction time for educational projects in Texas. However, 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. A prediction model of construction time has been developed based on the results of the study. This model will be useful to students taking courses related to cost estimating and construction project scheduling and also to professionals involved with construction industry.

Key words: Construction time, Construction Cost, Gross Floor Area, Educational Buildings.

Introduction

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[1,2]. 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.[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:

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

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 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[3] replicated the study to predict construction time for high-rise buildings in Australia; Kaka & Price[4] conducted a similar survey both for buildings and road works in the United Kingdom; Chan[5] investigated the effect of construction cost on time with particular reference to Hong Kong; and Choudhury & Rajan[2] conducted a study on residential construction projects in Texas. Hoffman et al. [6] 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 when the cost of construction is known.

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[7]. 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[8] study takes a similar view. They argue that construction cost, when decomposed, consists primarily of labor and material costs. They contend that while labor cost is a function of time, material cost of a building is a function of gross floor area. The time taken for construction, they claim, 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 of 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 with reference to educational projects in Texas.

Construction Time and Project Delivery Method

Construction procurement is the process of obtaining services and supplies for efficient and timely delivery of the end product. The major project delivery methods include (1) Design-Bid-Build, (2) Design-Build, and (3) Construction Management at Risk. Studies indicate that project performance is affected by project delivery method[9,10,11].

The trend in the use of project delivery system is changing rapidly. Project delivery system has evolved over the years. The medieval master builder was hired by an owner to design, engineer, and construct an entire facility. This system was common until the early 20th century. With changing technologies, it was necessary to change the type of delivery system that gave way to the Design-Bid-Build method. As the specialization of services increased, it was found that the interaction during design phase was extremely poor which resulted in inefficient designs, increased errors and disputes, higher costs, and ultimately longer schedule. This led to the Construction Management at Risk delivery system to improve the interaction among parties concerned and to overlap the design and the construction phases. Eventually, it was found necessary for owners to resort to a single source Design-Build contracting[12]. There is an increasing trend toward the use of the Design-Build delivery method in the public sector[9,13,14].

It is thus possible that project delivery method could play a role in construction performance time. The likelihood of an impact of delivery method on construction time of educational buildings was ascertained by including it in the time-cost relationship model.

Hypothesis

From a review of literature, it is hypothesized that the actual construction time of educational projects in Texas is affected by:

- Actual construction cost
- Gross floor area of construction
- Project Delivery Method

Methodology

Data Collection Procedure and Sample Size

Data for 39 educational construction projects were obtained from three Independent School Districts in Texas. It was collected in Spring 2009. Superintendents of these school districts were contacted by email. After making appointment, personal interviews were conducted with all three of them and data was collected. The sample consisted of data covering three methods of project delivery: Design-Bid-Build, Design-Build, and Construction Management at Risk. The sample size covered 13 schools each from all the project delivery method categories. All the schools were constructed between 2003 and 2008.

Variables and their Operationalization

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

Delivery (DELIVERY): It is the type of project delivery system used for delivering an educational construction project. This was a class variable consisting of three categories: (1) Construction Management at Risk (CMR), (2) Design-Build (DB), and (3) Design-Bid-Build (DBB). Two dummy variables were created from this class variable: (1) Construction Management at Risk (CMR) and (2) Design-Build (DB). These variables were labeled as LNCMR and LNDB after being transformed into its natural logarithms. Table 1 shows the process of creating the dummy variables and assigning values to them.

Tab1e 1. Dummy Variables for DELIVERY

DELIVERY	LNCMR	LNDB
CMR	1	0
DB	0	1
DBB	0	0

Results

Analysis

The time-cost relationship model developed by Bromilow et al.[1] (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 project delivery method along with construction cost, the model had to be modified. Following model encompasses all the variables that may have an effect on construction time performance:

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

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.

$$LNTIME = LNK + \beta_1 \, LNCOST + \beta_2 \, LNGFA + \beta_3 \, LNCMR + \beta_4 \, LNDB + \varepsilon \qquad (3)$$

Where

LNK = natural logarithm of K,
β_1, β_2, β_3, etc. = regression coefficients, and
ε = error term.

The results of the analysis are shown in Table 1.

Table 1. Stepwise Linear Regression Analysis for LNTIME

Variable Retained	Intercept (LNK)	Regression Coefficient	*t*	*p*<|*t*|	Critical Value of |*t*|
Intercept	-2.703		-5.455	<0.0001	2.02
LNGFA		0.454	10.208	<0.0001	
F-value of the Model = 104.212	*p*>Model *F*=< 0.0001	Model R^2 = 0.74 Adjusted model R^2 = 0.73			

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 0.74, and an adjusted R^2 of 0.73. It means that at least 73 percent of the variances in construction time of educational projects are explained by gross floor area alone.

In order to have a visual understanding of the relationship between construction time and gross floor area, a scatter plot diagram was produced (Figure 1). The diagram confirmed the results obtained by stepwise linear regression analysis. A residual plot indicated a good fit of the sample data (Figure 2).

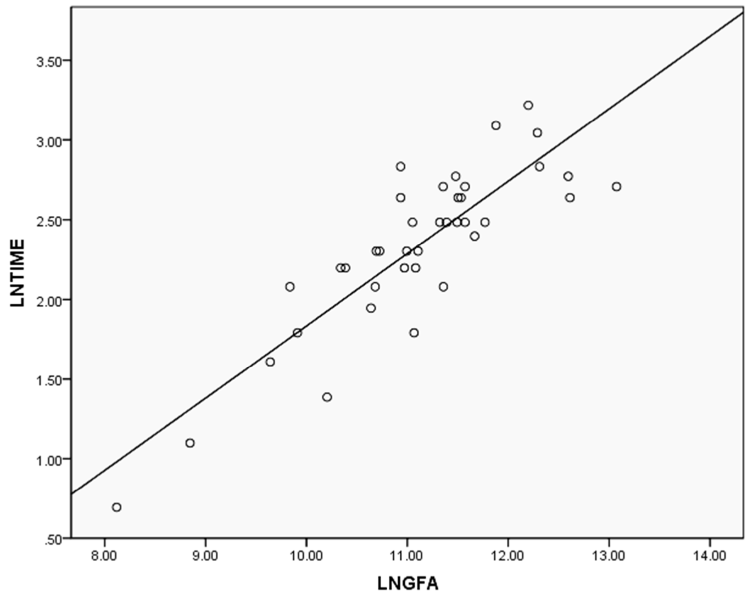

Figure 1: Relationship between LNTIME and LNGFA

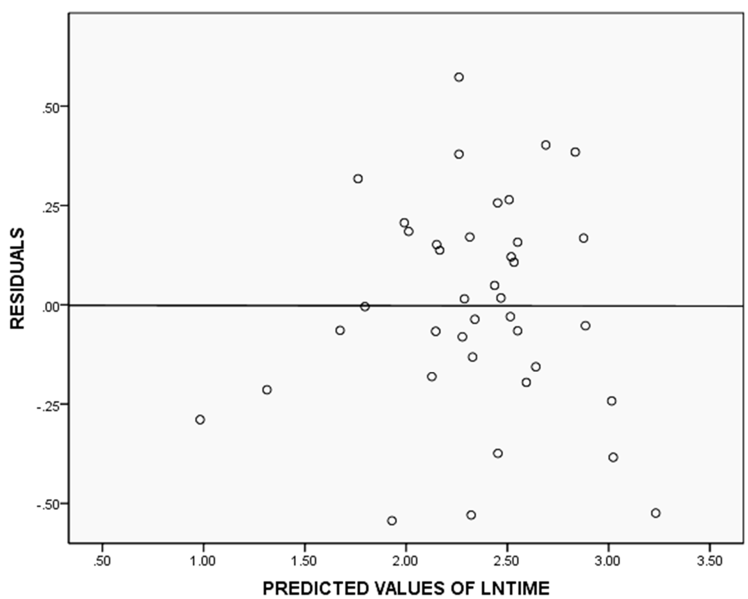

Figure 2: Residual plot

The prediction model for construction time of educational buildings was developed using results of the analysis. Bromilow et al.'s[1] 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 0.067. The model may be expressed as follows:

$$TIME = 0.067*GFA^{0.454} \quad (4)$$

This model can be used to predict the construction time for an educational project in Texas when the gross floor area in known. For example, if the gross area of a school building is, say 50,000 sft., the predicted construction time for the project would be about 9 months.

Conclusions

The results of the statistical analysis indicate that for an educational construction project in Texas, 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 production model when gross floor area is available. It can, thus, be assumed that gross floor area is a better predictor of construction time for educational buildings in Texas. Project delivery method does not play any role in predicting construction for educational projects.

The model will be useful for students of construction science, taking courses in estimating and construction project scheduling. The students are often required to participate in hypothetical bidding for construction projects. This model could be used as an effective tool for estimating project construction time based on estimated construction area for educational projects.

This study has been conducted using data for construction of educational buildings in Texas. The model developed provides an alternative and logical method for estimating construction time to supplement the prevailing practice of estimation predominantly based on individual experience. 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 educational buildings in Texas and cannot be generalized beyond the sample size. The study will hopefully generate enough interest to do further research for deriving models to predict construction time for projects in other sectors.

Bibliography

1. Bromilow, F. J., Hinds, M. F. & Moody, N. F. (1980). "AIQS survey of building contract time performance," Building Economist, 19(*2*), 79-82.
2. Choudhury, I. and Rajan, S. S. (2008). "Time-cost relationship for residential construction in Texas," The American Professional Constructor, 32(2), 28-32.
3. Ireland, V. B. E. (1985). "The role of managerial actions in the cost, time, and quality performance of high-rise commercial building projects," Construction Management and Economics, 3 (1), 59-87.
4. Kaka, A. & Price, A. D. F. (1991). "Relationship between value and duration of construction projects," Construction Management and Economics, 9(4), 383-400.
5. Chan, A. P. C. (1999). "Modeling building durations in Hong Kong. Construction Management and Economics," 17(*2*), 189-196.
6. Hoffman, G. J. et al. (2007). "Estimating performance time for construction projects," Journal of Management Engineering, 23(4), 193-199.

7. Walker, D. H. T. (1995). “An investigation into construction time performance,” Construction Management and Economics, 13(3), 263-274.
8. Love, P. E. D., Tse, R. Y. C., & Edwards, D. J. (2005). “Time-cost relationships in Australian construction projects,” Journal of Construction Engineering and Management, 131(2), 187-193.
9. Choudhury, I. and Pitkar, M. (2007). “An analysis of project delivery systems in commercial construction,” Journal of American Institute of Constructors, 31(1), 23-27.
10. Ling, F. Y. Y. et al. (2004). “Predicting performance of design-build and design-bid-build projects,” Journal of Construction Engineering and Management, 130(1), 75-83.
11. Chan, A. P. C., Scott, D. and Lam, E. W. M. (2002). “Framework of design criteria for design-build projects,” Journal of Management in Engineering, 18(3), 12-128.
12. El-Wardani, M. A., Messner, J. I., and Horman, M. J. (2006). “Comparing procurement methods for design-build projects,” Journal of Construction Engineering and Management, 132(*3*), 230-238.
13. Tulacz, G. (2006). “Design-build continues to grow despite weariness and price concerns,” ENR, 256(*23*), 38.
14. Yakowenko, G. (2004). “Megaproject procurement: Breaking from tradition,” Public Roads, 68(1), 48-53.