TIME-COST RELATIONSHIP FOR RESIDENTIAL CONSTRUCTION IN TEXAS

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SUMMARY

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 Brolmilow et al. in context with residential construction projects in Texas. The data for the study was obtained from about 55 completed residential projects. The results indicate that Bromilow et al.'s model holds good for the Texas Construction Industry at the level of significance (*p*-value) of <0.0001.

Key words: Construction time, Construction Cost, Residential Construction, Texas Construction Industry

INTRODUCTION

Objectives of the Study

There is an increasing need for prediction of construction time at planning and bid preparation stages for including a 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 science.

Large lot sizes, use brick and stone veneers, and extensive use of central heating and cooling, among others, are some unique features of residential construction in Texas. A time-cost relationship model developed by Bromilow, et al. (1980) and validated by few other researchers has been use to verify whether such a relationship holds good for the residential construction industry in Texas, despite the presence of these unique features. It is hypothesized that the total construction time of a residential project in Texas is positively correlated with the total construction cost of the project.

Review of Literature

Time and cost are two main 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.

A relationship between completed construction cost and the time taken to complete a construction project was first mathematically established by Bromilow (1974) and subsequently updated 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 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 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.

Taking a cue from Bromilow et al., 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. holds good for prediction of construction time if the cost of construction is known.

Limitations of the Study

Completion of construction projects is affected by numerous factors apart from the cost. Studies show a relationship between attitude of the workforce and management practices to the duration of a construction project (Ireland, 1986; Nkado, 1995).

A contractor may choose different crew sizes, equipment, and construction methods to complete the activities. These decisions may ultimately effect cost of a project and, thereby, the duration of construction. Adjustments are needed to change the resource assignments to optimize the resource allocations that yield the desired duration to a minimum cost. The ability to accurately predict the client's financial commitment, which also forms the basis of the contractor's eventual revenue, has many implications on the duration of a project. For large construction projects, consisting of independent units and for situations where a number of projects are concurrently running, an indication of an overall cash commitment can be crucial.

This study is limited to the validation of time-cost relationship developed by Bromilow et al. (1980) in Texas construction industry, particularly with reference to the residential sector. It does not incorporate the implications of other factors that are likely to influence the total time required for the completion of a construction projects.

METHODOLOGY

Data Collection

An instrument was prepared and mailed electronically to 450 residential construction companies in Texas, randomly selected from a list obtained from the Texas chapter of the National Association of Home Builders. The firms selected specialized in single-family and multi-family residential construction projects. Data related to 55 residential projects completed within last five years was obtained. Construction time and project cost of these residential works are shown in Table 1.

Project no.	Construction Cost (in $1000)	Construction time (in days)	Project no.	Construction Cost (in $1000)	Construction time (in days)
1	2800	630	29	128	110
2	1400	480	30	145	118
3	1350	360	31	775	150
4	225	280	32	700	160
5	800	360	33	790	180
6	166	130	34	650	200
7	101	88	35	650	155
8	199	125	36	270	132
9	167	125	37	208	210
10	173	148	38	248	193
11	2200	540	39	285	217
12	1825	405	40	335	129
13	925	310	41	693	302
14	750	280	42	774	358
15	1600	410	43	901	391
16	173	150	44	868	442
17	180	150	45	832	380
18	300	240	46	7800	750
19	189	180	47	8500	410
20	241	180	48	15000	1200
21	145	150	49	4500	300
22	160	130	50	7500	400
23	149	162	51	513	145
24	139	147	52	303	120
25	162	174	53	414	155
26	95	115	54	694	205
27	115	110	55	187	115
28	109	108			

Table 1 Construction time and cost of the residential projects

Variables and their operationalization

Construction Time (TIME): It is the actual time for completion of the project measured in working days.

Construction Cost (COST): It is the total cost of the construction of the residential projects measured in thousand US dollars.

Analysis

Data related to the construction time and cost was collected for 55 residential projects. SAS® statistical program was utilized for analysis of the data. A scatter plot of the data was prepared to analyze the relationship between the actual construction time and total project cost (Figure 1). The plot indicated a positive relationship between the variables. The data collected for the study was then used to validate the time-cost relationship model derived by Bromilow et al. (1980) for the Australian construction industry (see equation 1) using the following equation:
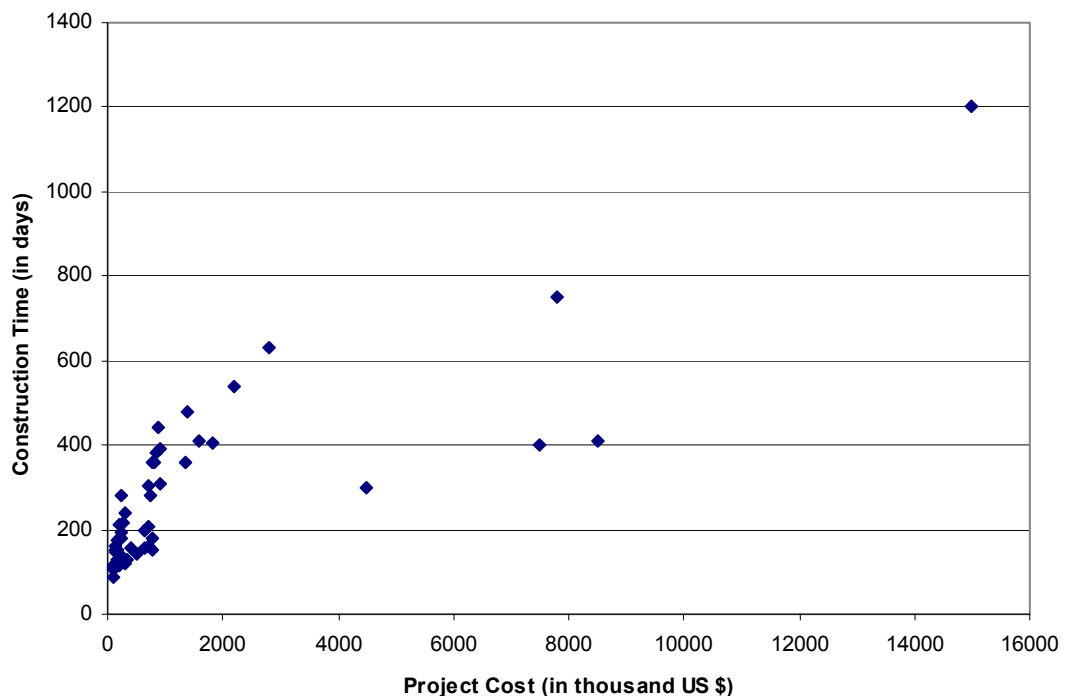
$$TIME = K*COST^{\beta} \qquad\qquad (2)$$

where

$TIME$ = duration of construction time in days,
$COST$ = completed cost of the project in thousand US \$,
K = a constant indicating the general level of time performance for a project worth one thousand US \$, and
β = a constant indicating how the time performance is affected by the size of the construction project measured by its cost.

Figure 1 Relationship between construction time and project cost

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

$$LnTIME = Ln\,K + \beta\,LnCOST \tag{3}$$

where

 LnTIME = natural logarithm of time,
LnK = natural logarithm of *K*,
β = coefficient of *LnCOST*, and
LnCOST = natural logarithm of cost .

RESULTS

The results of the analysis indicated a positive relationship between construction time and project cost for residential works in Texas. They are shown in Table 2.

Variable	Intercept (Ln K)	Coefficient Ln Cost (β)	T	p> $/T/$	Critical Value of $/T/$
Intercept	2.91		14.44	<0.0001	12.71
LnCOST		0.39	12.44	<0.0001	

Model R^2	0.7449
Adjusted Model R^2	0.7401
F-Value of the Model	154.77
Critical Value of F	5.32
p>Model F Value	<0.0001

Table 2 Simple Linear Regression Analysis for *LnTIME*

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 18.96.

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 of 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 quite high with an R^2 of 0.7449, and an adjusted R^2 of 0.7409. A residual plot indicated a good fit of the sample data (Figure 2).
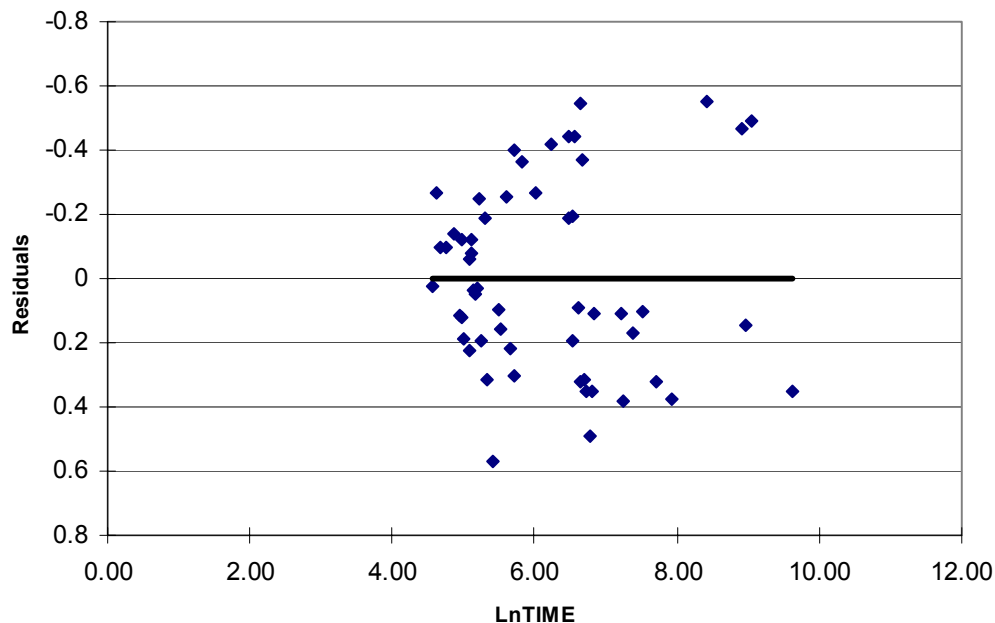
Figure 2 Residual plot

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 the 0.0001 level. It can therefore be concluded that the time-cost relationship for the residential industry in Texas can be expressed using the model developed by Bromilow et al. (1980). It can be expressed in the form:

$$TIME = 18.96*COST^{0.39} \qquad (4)$$

DISCUSSIONS

The results of the statistical analysis indicate that for a residential construction project in Texas, an increase in the construction cost results in an increase in the construction time. It is found that for a project worth us $1000, the construction time is 18.96 days for the project completion.

The model is useful for all parties associated with the construction industry to predict the mean time required for the delivery of a project, when the cost of the project is known. It provides an alternative and logical method for estimating construction time, both by bidders and clients, to supplement the prevailing practice of estimation predominantly on individual experience. The study will hopefully generate enough interest to do further research for deriving models for time-cost relationships of construction projects in other sectors and in construction industries in different regions.

Developing time-cost relationship models for different construction industries will have a far-reaching effect on international competitive bidding. Along with electronic bidding sets, an automated version of such a model could be made available to the prospective bidders to calculate a fairly accurate construction time for completion of the project. All that will be required is to create a project database containing, among other data, historical information about actual

construction cost and time for similar type of projects. This database may be made accessible to the bidders from any place, at any time, using web technology.

The study was limited to investigate only the effect of cost on construction time in the context of residential projects in Texas, 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, construction materials, and project environment, and analyze their effect on total construction time.

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