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Regression Analysis to Determine the Minimum Time Value in the Cost-Plus-Time Bidding Method

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Abstract - Alternative contract methods (ACMs) has a role, one of which is to reduce the impact due to delays in project completion time. Bidders may submit bids for brief periods, which may even result in additional project time. Determining the minimum time value in the A+B bidding method by State Highway Agencies (SHA) is a job that needs serious attention. This paper uses data from three DOTs with three types of projects, constructing the model equations generated from the regression analysis to determine the minimum time value that can help the owner assess the proposed bids.

***Keywords*:** A+B, bidding method, time value, highway project, regression analysis

1. Introduction

The existence of other activities on the highway that affect the smooth flow of traffic will result in losses for road users due to its impact, including work activities such as lane widening, rehabilitation/reconstruction on pavement, bridge replacement, and the like. Efforts to reduce this impact have been carried out by implementing ACM, which forces the winning contractor to reduce the duration of the work. Currently, ACM continues to be carried out in almost all states in the United States [1], including European countries [2]. One type of ACM is the cost-plus-time (A+B) bidding method which gives bidders a portion of the project duration bid as part of their total bid [3], [4].

Along with the development of the use of this method, there is an interesting phenomenon to be studied further, namely the determination of the lower limit of the time value of bidders when submitting bids using the A+B method. This is because bidders often try to suppress the number of unreasonable duration bids to win the bid. Several studies have reported that the actual duration of the project exceeds the period in the contract [5] and that there is an increase in project costs due to the impact of changing orders [6] due to these problems. This paper tries to develop a formula model to help the agency determine the minimum value for the number of durations used as a standard in assessing bidders' time value bids.

2. Construction cost and time relationship

In some types of ACM (i.e. A+B, I/D, and Lane rental), a time value concept is involved in calculating the contractor's final bid value representing the daily road user social costs (DRUC) [7]. For the A+B method, the contractor's bid includes part A as the value of construction costs ($), and the bidder determines the time (days). Furthermore, the DRUC ($) is determined by the highway agent, which is then multiplied by the project time (days) and produces part B ($) [8]–[10]. The lowest A+B number is the winning bidder.

In implementing construction project activities, cost and time are described as interrelated relationships. This time-cost relationship forms a relationship curve with a minimum cost point with an optimum project time/duration [3]. This indicates that even a slight shift in the time value of the project will result in cost overruns. The study of the time-cost functional relationship in the A+B method has produced a model for determining the minimum time value and incentives [3], [11]–[13]. In addition, the relationship between project costs and time has also been studied when separating the perspective of contract types such as traditional/conventional types, pure A+B, and A+B combined with incentives/disincentives and their impact on the change order aspect (A+B+I/D) [6], or in determining the level of the cost-time trade-off [14]. A follow-up study [15] allows the use of the relationship model constructed by regression analysis to be carried out in the optimal strategy model of their proposed time-cost quadratic functional relationship.

3. Data analysis and model establishment

3.1. Data collection

Previous research has been conducted by [3], [12], [16] using the same data used by [13] to find a functional model between cost and time in the A+B and I/D method. They used data on completed projects from the Florida Department of Transportation (FDOT), as many as seven A+B projects, seven I/D projects, and eight no excuse bonus projects that were completed between 1996-1999.

This study will use data collected from 36 completed projects using the A+B bidding method (Table 1). The data includes 7 A+B projects used in the previous study, plus 10 FDOT projects for the 2018-2021 fiscal year, 10 Colorado DOT (CDOT) projects for 2012-2020, and 9 Minnesota DOT (Mn/DOT) projects for the 2000-2005 fiscal year [17].

Table 1: Total data for each type of project A+B.

Type of project	FDOT	Mn/DOT	CDOT	Total
Widening	5	1	2	8
Rehabilitation	11	6	4	21
Bridge	1	2	4	7
Total	17	9	10	36

3.2. Regression analysis

The analysis in this study adopted the method done by [3]. Therefore, several terms in the analysis used by them will also be adopted with the same meaning for this paper, such as Award bid, Present (Final) construction cost, Days used, and Present (Final) contract time. For this study, the determination of the internal relationship between cost and time was initiated by equating the monetary value of each project with the National Highway Construction Cost Index (NHCCI). The equating is because of implementing those projects in different years (1996 – 2020). For this equivalence, the NHCCI is used according to index values released by the Minnesota Department of Transportation [18] for all project data used. Several state DOTs have their NHCCI calculations. However, [19] reported that FDOT uses other states' HCCI or a third-party cost index. Then data from CDOT is also calculated in the same way using Eq. (1).

$$\mathrm{Cost}_A = Cost_B \left(\frac{NHCCI_A}{NHCCI_B}\right) \tag{1}$$

For this study, Cost_A is the project's cost in the last year (2018), and Cost_B is the project cost in the project launch year. Meanwhile, NHCCI_A was the construction cost index in 2018, and NHCCI_B was the construction cost index in the project launch year. Seven projects worked in 2019-2020 were not included in the analysis because the NHCCI for that year had not been released.

Regression analysis is built by taking into account the relationship between additional cost from bid award (Present construction cost - Award bid) as the dependent variable, and Reduction of contract time (Present contract time - Days used) as the independent variable. Regression analysis of the existing data using the Statistical Package for Social Sciences (SPSS) software. In addition to 7 projects (2019-2020), seven other projects were also deleted because they had non-positive variable values, leaving 22 in the analysis. The results obtained from this relationship indicate that the highest R^2 is in the quadratic model (0.765) and the cubic model (0.761), with the model significance of the F test being 0.000 < 0.05 for both (Table 2).

Table 2: Summary of various regression analysis.

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.479	15.657	1	17	.001	37328.524	21761.83		
Logarithmic	.259	5.937	1	17	.026	-554453.989	451631.91		
Inverse	.149	2.968	1	17	.103	1171539.232	-4140789.91		
Quadratic	.765	26.091	2	16	.000	587812.023	-23534.94	446.677	
Cubic	.791	18.905	3	15	.000	210693.704	32331.75	-779.622	6.544
Compound	.298	7.200	1	17	.016	145938.570	1.03		
Power	.320	8.007	1	17	.012	38999.004	.74		
S	.338	8.690	1	17	.009	13.615	-9.17		
Exponential	.298	7.200	1	17	.016	145938.570	.03		
Logistic	.298	7.200	1	17	.016	6.852E-6	.98		

3.3. Model development

To continue the analysis, the quadratic model was chosen to determine the equation because the p value of each parameter is more significant than the cubic model. The regression model formulation is shown in Eq. (2) which is simplified to Eq. (3).

$$C - C_0 = 587812.023 - 23534.94(D_0 - D) + 446.677(D_0 - D)^2 \quad (2)$$

$$C = (1 + C_0) - 0.04(D_0 - D) + 0.00076(D_0 - D)^2 \quad (3)$$

Where, C = Present construction cost; C_0 = Award bids; D = Days used; and D_0 = Present contract time. Furthermore, mathematical adjustments were made using the partial differential method to the equations built and the minimum D value as in Eq. (4).

$$\mathrm{D}_{min} = \mathrm{D} = \frac{\mathrm{D}_0 - 52.689}{2} \quad (4)$$

4. Conclusion

Previous researchers have built several models with less data than the ones used in this study. However, the concept created in this study uses the equalization of the value of money because of different project times. Although the data is still a combination of several types of projects and locations, at least it can be described as a model for determining the minimum time value. In the future, it is necessary to separate the types of projects because there are differences in the characteristics of each project to find a truly accurate model.

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