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Applicability of Bromilow´s Time-cost Model for Residential Projects in Slovakia

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Abstract

The concept of construction time has been mentioned by most researchers as one of the key factors of a successful project. Time-cost model for rapid estimation of construction time appeared in the world some fifty years ago and the most mentioned is model developed by Bromilow. The purpose of submitted research is to validate Bromilow´s time-cost (BTC) model and identify constants in BTC model in context with residential construction projects in Slovak construction conditions. The data for the study were obtained from 28 residential projects completed within the period 2010–2013 in regions of Slovakia. The data were analyzed using classical correlation and regression analysis.

Key words: Bromilow´s time-cost (BTC) model, construction time, construction cost

1 Introduction

Contract time overrun is a common problem in the construction industry. Construction delays emanate from a diversity of origins including contractor´s faults, changes in design, other unforeseen events such as inclement weather and industrial relations disputes or just simply an overly optimistic predetermined contract duration [1]. Accurate estimate of construction time and cost is very important in negotiating contract terms. In the construction industry, contractors usually use previous experiences to estimate the project duration of a new project[3]. It would be very beneficial if there were reliable models of dependence for the factors of construction to facilitate estimation of construction time. The first model of time-cost dependency was conducted in Australia by Bromilow in 1969. It is called Bromilow´s time-cost (BTC) model and it enables the construction period to be calculated according to the estimated final cost of a project. This model was since year 1969 validated and adapted to the construction conditions of other countries by researchers from these countries. The purpose of submitted study is to validate Bromilow´s time-cost model and identify constants in BTC model in context with residential construction projects in Slovak construction conditions. 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.

2 Theoretical background

Bromilow's study in 1969 revealed that the time taken to construct a project is highly correlated with the size as measured by cost. Construction time in working days could be expressed as a function of cost based on the exponentional curve of best fit and upper and lower quartile limits derived from the historical data [1]. On this basis Bromilow´s time-cost model was defined by formula 1:

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

where *T = construction time (in days),*
C= estimated cost of project (in million dollar),
K= a constant describing the general level of time performance,
B= a constant describing how the time performance was affected by project size as measured by cost.

The constants *K* and *B* may vary depending on the construction conditions of the country, but also depending on the construction sector. As already mentioned BTC model was several times validated and adapted for different countries by many researchers [1,3,6,7]. Some of them are summarized in Table 1 [5,6,7].

Table 1: *K* and B values for some BTC models

Researcher	Year	Country	Construction segment	Unit of measure	K	B
Bromilow	1969	Australia	Public projects	million dollar	211	0,30
			Private projects		156	0,30
			Overall projects		177	0,30
Bromilow	1974	Australia	Overall projects	million dollar	313	0,30
Ireland	1983	Australia	Overall projects	million dollar	155	0,47
Ireland	1985	Australia	High-rise buildings	million dollar	219	0,47
Bromilow	1988	Australia	Public projects	million dollar	186	0,38
			Private projects		136	0,28
			Overall projects		164	0,30
Kaka and Price	1991	United Kingdom	Public projects	-	398	0,32
			Private projects		274	0,21
Yeong	1994	Australia	Overall projects	million dollar	269	0,21
		Malajzia	Public projects		518	0,35
Kumaraswamy and Chan	1995	Hong Kong	Public projects	-	188	0,26
			Private projects		160	0,31
Ng, Mak, Skitmore, Varnam	1998	Australia	Public projects	million dollar	129	0,32
			Private projects		132	0,30
			Overall projects		131	0,31
Chan	1999	Hong Kong	Public projects	-	166	0,28
			Private projects		120	0,34
			Overall projects		152	0,29
Chan	2001	Malajzia	Overall projects	-	269	0,34
Choudhury et al	2002	Bangladesh	Health sector	-	5	0,27

Choudhury and Rajan	2003	Texas, USA	Residential construction	thousand dollar	19	0,39
Czarnigowska and Sobotka	2009	Poland	Road	thousand polish zloty	3	0,46
Žujo, Car-Pušić	2009	Bosnia and Herzegovina	New construction Reconstruction	100 thousand convertible mark	70 79	0,52 0,41

However, the results of some studies show that the relationship between construction time and construction cost showed very little correlation coefficient. Based on this, we can argue, that the formula 1 is not applicable in some construction conditions in some countries [2], [4].
The task of this research is to determine degree of dependence (correlation coefficient) between time and cost for residential projects in Slovakia. If the correlation coefficient is high we can also determine constants in BTC model for residential projects in Slovak construction conditions.

3 Research methodology

Primary data of 28 residential projects were collected from different regions of Slovakia. Information obtained in respect of each project included: project type, construction site, final construction cost, commencement date, completion date. The data were limited to comparable projects completed within the period from 2010 to 2013. This is because the period was considered to have experienced almost the same economic climate. Construction time and cost details of the residential projects surveyed are shown in Table 2.

Table 2: Construction time and cost of the residential projects

Project no.	Construction cost (in mil. €)	Construction time (in days)	Project no.	Construction cost (in mil. €)	Construction time (in days)
1	1,8	480	15	55,0	1410
2	2,5	600	16	4,5	630
3	3,5	480	17	97,0	1530
4	1,7	360	18	32,4	840
5	1,8	540	19	14,0	780
6	2,0	480	20	2,7	480
7	2,7	450	21	6,4	570
8	3,0	570	22	3,8	690
9	6,4	720	23	4,2	450
10	2,8	420	24	21,5	840
11	4,8	480	25	9,0	630
12	1,4	480	26	9,6	780
13	2,8	360	27	100,0	900
14	6,4	780	28	31,5	1080

Graphical tool - scatter plot was used on initial examination of the selected parameters relationship. The data is displayed as a collection of points, each having the value of one variable determining the position on the horizontal "x" axis and the value of the other variable determining the position on the vertical “y” axis. Scatter plot was made in software Excel, where on the “x” axis there are values of construction cost in million euro and on the “y” axis there are values of construction time in days (Figure 1). We can see, that between construction cost and construction time, there is a relationship that can be described by the exponentional curve.

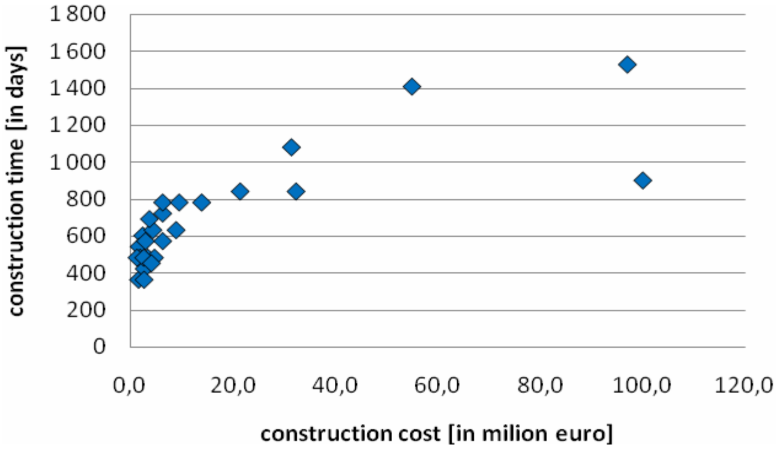

Figure 1: Scatter plot of the origin data

It is evident (of Figure 1) that there is not a linear relationship between construction time and construction cost, hence it is necessary model transformation for further statistical analysis. Based on the theoretical knowledge that the time-cost relationship is defined by the origin Bromilow model (1), it was transformed by natural logarithms to the linearized form as follows:

$$\ln T = \ln K + B * \ln C \tag{2}$$

where *lnT = natural logarithm of time,*
lnK = natural logarithm of K,
B = coefficient of lnC, and
lnC = natural logarithm of cost.

Subsequently classical linear regression and correlation technique was used to analyze the linearized model.

4 Results and interpretations

Pearson correlation coefficient values of 0.8816 points the high degree of dependency between natural logarithm of time and natural logarithm of cost. Correlation is significant at the 0.05 level (2-tailed).

The final linear regression model, where dependent variable is natural logarithm of time and independent variable is natural logarithm of cost, has the high coefficient of determination and adjusted coefficient of determination values of 0.776 and 0.768, respectively. It is shown that over 76 percent of the variance in natural logarithm of time estimation can be explained by natural logarithm of cost. This regression model is statistically significant at the 0.05 level. It has been considered very good in terms of goodness of fit. It can therefore be concluded that the time-cost relationship for the residential projects in Slovakia can be expressed using the model defined by formula 1 developed by Bromilow. However, it is still necessary to determine constants K and B in the BTC model.

The aim of the classical linear regression analysis is also to determine the coefficients for regression function (coefficients B_0 a B_1) in form:

$$Y = B_0 + B_1 * X \tag{3}$$

where *B_0 - constant that expresses the expected level of regression function at zero value of the independent variable,*
B_1 - regression coefficient, which expresses the amount of units of dependent variable "Y" changes when the independent variable "X" will change the one unit of measure.

Regression coefficients for transformed model were defined as B_0 = 5.951, B_1 = 0.263 and regression function in form:

$$Y = 5.961 + 0.263 * X \tag{4}$$

Based on the formula 2 and formula 4 it can be concluded that constants K and B for Bromilow´s relationship for residential projects in Slovakia were defined:

$$\ln T = Y\,,$$
$$\ln K = B_0 = 5.951\,,$$
$$\mathbf{B} = B_1 = \mathbf{0.263}\,,$$
$$\ln C = X\,.$$

The value of *lnK* is required to be transformed to *K,* using an exponential function as we can see in formula 5.

$$\mathbf{K} = e^{5.951} = \mathbf{384} \tag{5}$$

Bromilow´s time-cost model in context with residential construction projects in Slovak construction conditions then we can adopt in the form:

$$\mathbf{T} = \mathbf{384} * C^{0,263} \tag{6}$$

where *T = construction time (in days),*
C= estimated cost of project (in million euro).

The results of the study indicate that for a residential construction project in Slovak construction conditions, an increase in the estimated cost results in an increase in the construction time. It is found that for a residential project worth us one million euro, the construction time is 384 days for the project completion.
Time-cost model for construction time estimation (formula 6) was created by statistical analysis of the real data (Table 2). Scatter plot was created from that data (Figure 1) and point which represents residential project number 27 (with position data 100; 900) appears to be

extreme. Because of this, it was necessary to exclude this project from the data set and to verify the extreme value impact on the resulting model.

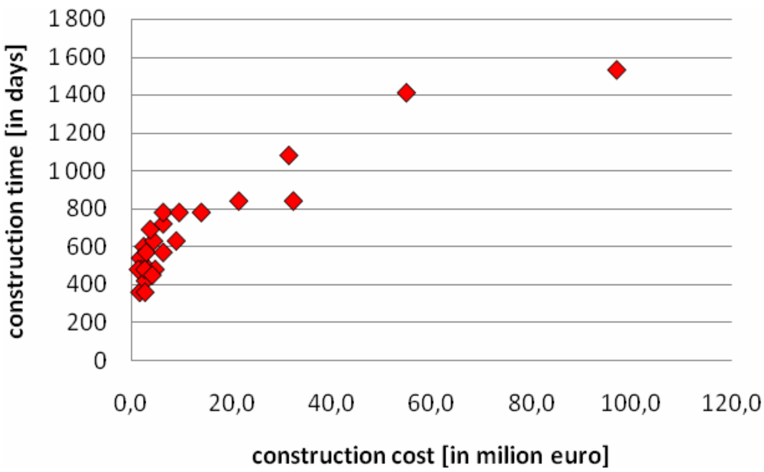

Figure 2: Scatter plot of the adapted data

Adapted set of data (Figure 2) was analyzed by classical linear regression and correlation technique and another time-cost model for construction time estimation was defined:

$$\mathbf{T} = \mathbf{386} * C^{0,295} \tag{7}$$

where *T = construction time (in days),*
C= estimated cost of project (in million euro).

Based on the model (formula 7) it was found that for a residential project worth us one million euro, the construction time is 368 days for the project completion.

Then, curves for both models (formulas 6, 7) were created and compared (Figure 3).

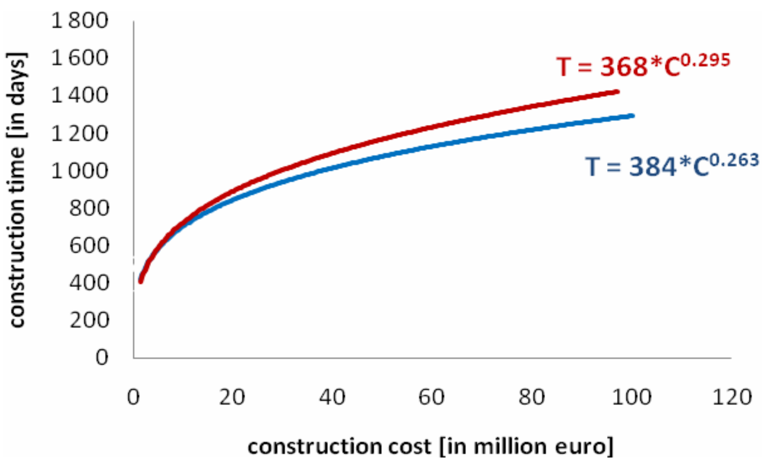

Figure 3: Two time-cost models (formulas 6, 7) and their comparison

From Figure 3 it is evident that there is a little difference in the construction time estimation using the formula 6 and formula 7 for the project which construction cost is under 20 million euro, and therefore, it is possible to estimate the construction time using one of the models. For project with projected construction cost is over 20 million euro, it is appropriate to estimate construction time by both models and thus define the interval of construction time estimation.

Subsequently model defined by formula 6 and model defined by formula 7 were tested on new database with the total of 7 residential projects (Table 3) and results are estimated as satisfactory.

Table 3: Results of application of model on new database

Project no.	Construction cost [mil.eur]	Actual time T_A [days]	Estimated time model (6) $T = 384*C^{0.263}$ [days]	Estimated time model (7) $T = 368*C^{0.295}$ [days]
1.	2,12	480	468	460
2.	1,07	390	391	375
3.	1,27	360	409	395
4.	0,95	390	379	362
5.	0,51	270	322	302
6.	3,50	450	534	533
7.	1,60	510	435	423
8.	56,8	1230	1111	1212

As already mentioned, the relationship between cost and time is defined by power function and this relationship is expressed by the constant *B*. The study was limited to analyzing only the effect of cost on construction time in the context of residential projects in Slovakia, providing all other variables constant.

5 Conclusion

After being confirmed many times in the world, it is able to point out that the credibility of Bromilow´s time-cost model was proved also for Slovakia. This is just the first research of this kind and it only presents an introduction to further researches in defining models for rapid estimation of construction time. Obtained mathematical model is applicable only for residential projects in Slovakia. The study was limited to analyzing only the effect of cost on construction time in the context of residential projects in Slovakia, providing all other variables constant. For future studies, it will be useful to include other variables such as gross floor area or building volume, number of residences, shape of building, number of stories, and analyze their effect on total construction time.

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