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Construction project completion time: a predicting approach for bids

Tiempo de finalización del proyecto de construcción: un enfoque predictivo para las ofertas

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Abstract
Precise estimation of the completion time of the project at the initial stages of the project is crucial for the preparation of the tenders. Conventionally, it is done by the engineers inaccurately using their experience with the projects which is not backed by any mathematical models. This study develops the time-cost relationship equations which can effectively estimate the delivery date of construction projects in Pakistan. This enhances the decision making of the professionals to accurately predict the time of the project.
key words: BTC model, project time, relationship of time-cost, regression

Abstracto
La estimación precisa del tiempo de finalización del proyecto en las etapas iniciales es crucial para la preparación de las ofertas. Convencionalmente, los ingenieros lo hacen utilizando su experiencia con los proyectos de manera incorrecta, lo que no está respaldado por ningún modelo matemático. Este estudio desarrolla las ecuaciones de relación tiempo-costo que pueden estimar efectivamente la fecha de entrega de los proyectos de construcción en Pakistán. Esto mejora la toma de decisiones de los profesionales para predecir con precisión el tiempo del proyecto.
palabras clave: modelo BTC, tiempo del proyecto, relación tiempo-costo, regresión

1. Introduction

Cost, time, quality, and satisfaction of the projects main stakeholders are considered to be the key factors to measure the overall success of any construction project. Among those the factors of cost and time have found to have a profound effect on the success of the project as no project is considered as successful if it exceeds the proposed cost and date of delivery (Gündüz, M., Nielsen, Y., and Özdemir, 2013). In many studies it has been observed that these two factors have a substantial relationship between them (Chan, 2001), (Jagboro, 2006), (Choudhury & Sanampudi, 2008). The client wishes to complete his project as soon as possible so that the project

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can be used for the purpose for which it was built. The client also does not wishes to exceed the proposed cost of the project. The constructor on the other hand also wants to finish the project as soon as possible, because he can maximize his profit by getting other projects. The client also wants to finish the project in the proposed budget mainly to save its reputation. The completion of any construction project on the proposed time and cost is easier said than done because it depends on several factors. Studies demonstrate this relationship of cost and time by showing a cost-time trade-off. Generally, contractor assigns varying quantities of construction workers, various types of construcion equipments and different constriction methodogies which ultimately affect both the cost and the time of the project completion. This elaborates that these both factors of time and cost have strong interdependence. (Sousa, V., Almeida, N., Dias, L., and Branco, 2014), (Owalabi et al., 2014).

Accurate estimation of the projects time is of great concern to all the project stakeholders as the project which exceeds the scheduled timeline creates a severe breach of the expectation of the stakeholders (Aynur Kazaza, 2012). In Pakistan, however, rarely any project is completed on time (Hussain & Ahmed, 2018). The accurate estimate of the projects completion time is cumbersome mainly because the construction process, being extremely complex and fragmented, depends on widely varied participants and activities. It has further been made complex by ever-increasing demands of clients and the market. Researches conclude that among other factors the inefficient management of time, cost, and change orders of the projects influence the success of the project profoundly. (Aynur Kazaza, 2012), (Gunduz et al., 2013), (Habibi et al., 2018).

It has been widely accepted that the accurate forecast of the construction time during its planning and bidding phase is desirable (Irfan et al., 2011). Professionals, however, rely on their experience for forecasting the time of the project which is not backed by any mathematical model and therefore sometimes gives inaccurate results. Researchers have therefore tried to solve this problem by using some statistical techniques to develop mathematical equations that can be used to predict the appropriate time of the projects (Czarnigowskaa, 2013), (Kanoglu & Sezgin, 2004), (Leśniak & Zima, 2018). Proper Planning and bid organizing stages need realistic project time estimates to award contracts (Jeong et al., 2009), (Zavadskas et al., 2018). As discussed earlier, builders use their previous experience to estimate the duration of the new project. Although much study has been conducted in Pakistan for determining the causes of the delays and their remedial measures, yet there is dire need to develop accurate models for predicting the time of the project in its first place.

This research, therefore, appraises the relationship between construction projects' cost & time. Further, this study also develops three mathematical equations for estimating the length of the building project dependent on the projects' costs in developing countries such as Pakistan. These equations can supplement the decisions by predicting the realistic projects' time which can be used in bids preparations by the contractors for their forthcoming projects.

2. Time-Cost Models

Time-cost models are used globally to predict the time factor of the construction project from its cost factor. Among many, the most widely adopted time-cost model is Bromilow's Time-Cost (BTC) model (Son et al., 2019) (Sousa & Meireles, 2018)(Innocent et al., 2018). The initial time-cost model was developed by Bromilow in 1974. Later it was modified and updated in 1980 (Sousa, V., Almeida, N., Dias, L., and Branco, 2014).

This model's equation describes meaning project time as a function of the known project as given below.

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

Where;

T = is time in working days from the date of possession of the project site to the conclusion of the Project,

C = is the cost of the building project accomplished in Millions of Pakistani Rupees, maintaining all expenditures equal to the commitment and stuff rates as constant.

K = is a constant suggesting the average time consumed per 1 million costs of the construction projects; and

B = is a constant description of how the time output is affected by the size of the construction project when its cost is measured

This time-cost relationship model suggests a construction project's duration is mainly a feature of the overall cost. It gives origin to all parties concerned with the construction phase to determine a reasonably reliable possible duration of any construction project in days, considering the project's estimated cost.

3. Model Validation

It is crucial to validate the generated model before its application in the field. This is one of the essential aspects of the models derived from statistical procedures that can show the validation of prediction models.

For this purpose, there are a variety of techniques available for the validation of the data. Among others, the most widely accepted tests used are R2 and Mean Absolute Percentage Error (MAPE) (Hyndman & Koehler, 2006). The MAPE is effectively used to check the proximity of fit to the models and its reliability. To test the closeness of the fit of the models, the Percentage Error (PE) is determined using the following expression, which is expected to be ± 10 percent when considering it quite well.

$$\text{MAPE} = \frac{1}{n}\sum_{i=1}^{n}\frac{\left|(Predicated\ Duration)^i - (actual\ Predication)^i\right|}{\left|(actual\ duration)^i\right|} \times 100 \qquad (2)$$

Therefore, these two tests were conducted to validate the time-cost-relation model established in the study.

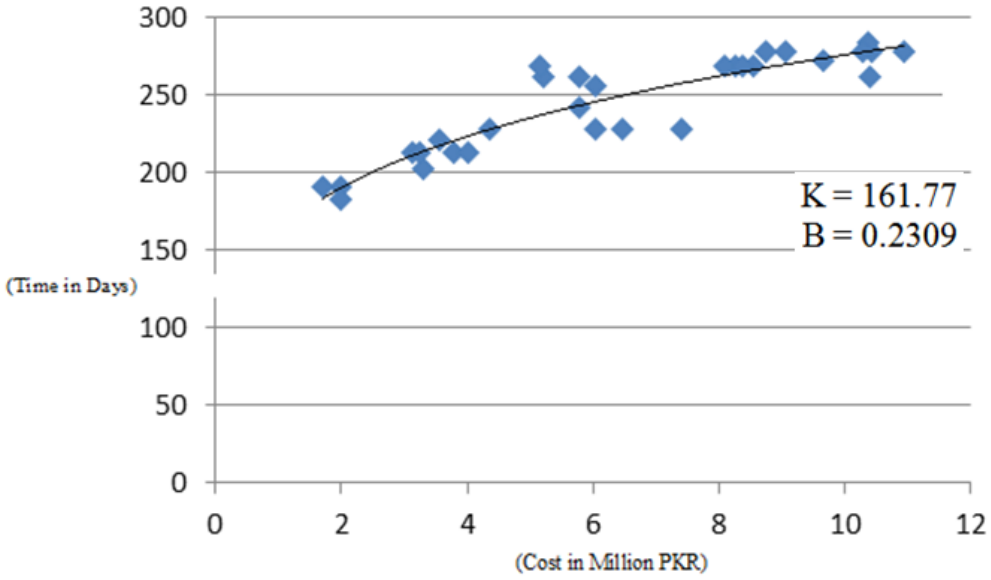
4. Data Collection & Analysis

This research analyzes the relationships between projects time and costs using the BTC model. The cost and time data for 30 different projects were collected from National Engineering Services, Pakistan (NESPAK), which is a semi-government department working in various construction projects in Pakistan. The data collected for the projects are rehabilitation drainage projects. The cost and time data for different projects were also collected from 30 different projects from the Works & Services Department which is a governmental agency for development projects. Finally, the cost and time data for different projects were also collected from 30 different projects from the Hyderabad Development Package. The reason choosing 30 projects is to make consensus between all three cases. These projects were from annual plan of all selected departments. The data has been collected personally by vising these offices and assuring the selected departments regarding data privacy and used policy. This model will, therefore, be used to estimate the time duration for forthcoming projects of the same nature. To collect the data a questionnaire was developed. Lastly, the data is analyzed to obtain results using linear regression analysis

5. Results & Discussion

The linear regression analysis has been carried for the cost and time data collected for 30 different projects from NESPAK “Figure 1” is showing the fitting trend of the data sets.

Figure 1
Regression Fitting for NESPAK



The findings indicate that the "K" constant which shows the average time consumed per 1 million costs of the construction projects is found to be 161.77, while the "B" constant description of how the time output is affected by the size of the construction project when its cost is measured constant is found to be 0.2309. Hence, the final equation showing the relationship between cost and time is given below.

$$T = 161.77\ C^{0.2309} \qquad (3)$$

The validation of the equation by R^2 value is estimated to be 0.85. This shows it to be reasonably suitable to utilize this equation for the prediction of the time for the construction projects having drainage rehabilitation projects nature in Pakistan. Whereas, the results of the second validation technique MAPE test has been shown. (see Table 1)

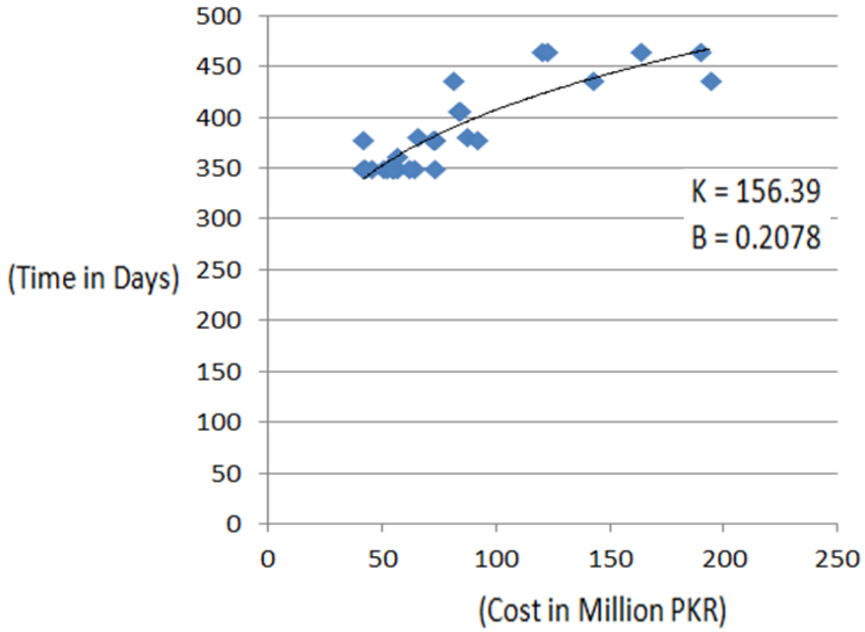
Table 1
MAPE Validation Results

S. No.	Actual Time	Predicted Time	MAPE	Remarks	S. No.	Actual Time	Predicted Time	MAPE	Remarks
1	261	277.8066	6.43		16	283	277.5685	-1.91	
2	212	210.5069	-0.70		17	227	256.6992	13.08	NA
3	261	236.9065	-9.23		18	227	244.9653	7.91	
4	261	242.5329	-7.07		19	227	248.7654	9.58	
5	241	242.5027	0.62		20	227	227.2668	0.11	
6	190	189.6024	-0.20		21	278	266.9321	-3.98	
7	268	265.5386	-0.91		22	278	276.9554	-0.37	
8	212	219.8864	3.71		23	190	182.807	-3.78	
9	278	277.8813	-0.04		24	255	244.8959	-3.96	
10	202	213.1512	5.52		25	277	280.9714	1.43	
11	278	269.0245	-3.22		26	268	262.021	-2.23	
12	220	216.753	-1.47		27	212	223.0678	5.22	
13	212	212.2211	0.10		28	268	264.1189	-1.44	
14	268	263.4411	-1.70		29	272	272.953	0.35	
15	182	189.3566	4.04		30	268	236.058	-11.9	NA

MAPE accepts the variation in the result of up to 10% (Rob J. Hyndmana, 2006). The table indicates that two of the predictions exceed the limit of ± 10% and therefore can not be considered as satisfactory whilst the remaining forecasts are in an acceptable limit. The overall variation in the percentage of the predicted duration is ±6.66% in total, which is quite satisfactory as per MAPE theorem.

Similarly, linear regression analysis also carried out for recently completed projects by the Works & Services Department. “Figure 2” is showing the fitting trend of the data sets.

Figure 2
Regression Fitting for the Works & Services Department



The findings indicate that the “K” constant which shows the average time consumed per 1 million costs of the construction projects is found to be 156.39, while the “B” constant description of how the time output is affected by the size of the construction project when its cost is measured constant is found to be 0.2078. Hence, the final equation showing the relationship between cost and time is given below.

$$\mathbf{T = 156.39\ C^{0.2078}} \qquad (4)$$

The validation of the equation by R^2 value is estimated to be 0.76. This shows it to be reasonably suitable to utilize this equation for the prediction of the time for the construction projects under the Works and Services department of Pakistan. Whereas, the results of the second validation technique MAPE test has been shown. (see Table 2)

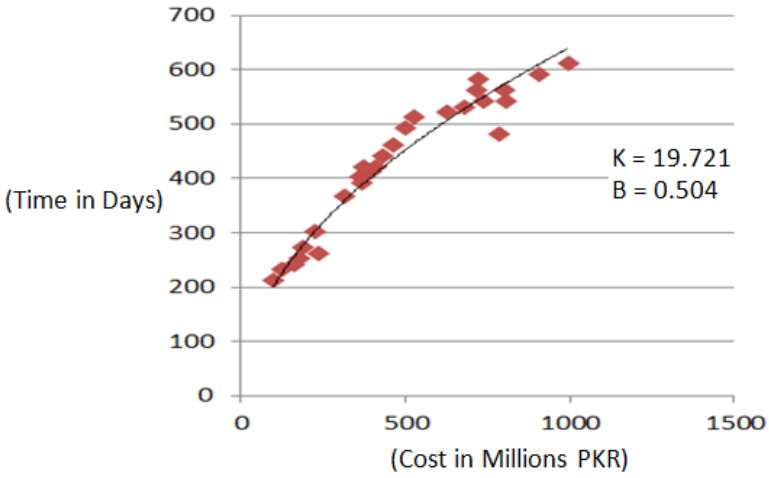
Table 2
MAPE Validation Results

S. No.	Actual Time	Predicted Time	MAPE	Remarks	S. No.	Actual Time	Predicted Time	MAPE	Remarks
1	348	335.0889	-3.71		16	435	457.8726	5.258076	
2	348	365.0159	4.88		17	464	415.1083	-10.53	
3	377	375.3768	-0.43		18	348	336.2799	-3.36	
4	348	356.3706	2.40		19	406	386.4786	-4.80	
5	348	340.2924	-2.21		20	348	354.419	1.84	
6	348	336.1241	-3.41		21	464	416.746	-9.18	
7	377	375.5334	-0.38		22	348	347.8124	-0.05	
8	406	385.7187	-4.99		23	435	383.6731	-11.79	NA
9	464	442.428	-4.64		24	360	356.6377	-0.93	
10	348	362.694	4.22		25	348	350.6906	0.77	
11	348	375.0776	7.78		26	348	353.0757	1.45	
12	377	334.97	-11.1	NA	27	377	374.7911	-0.58	
13	380	389.3074	2.44		28	377	393.2865	4.32	
14	435	430.0212	-1.14		29	380	367.0777	-3.40	
15	464	455.8722	-1.75		30	348	335.0889	-3.71	

MAPE accepts the variation in the result of up to 10% (Rob J. Hyndmana, 2006). The table indicates that two of the predictions exceed the limit of ± 10% and therefore can not be considered as satisfactory whilst the remaining forecasts are in an acceptable limit. The overall variation in the percentage of the predicted duration is ±6.66% in total, which is quite satisfactory as per MAPE theorem.

Likewise, linear regression analysis also carried out for recently completed projects by Hyderabad Development Package (HDP). “Figure 3” is showing the fitting trend of the data sets.

Figure 3
Regression Fitting for Hyderabad Development Package



The findings indicate that the “K” constant which shows the average time consumed per 1 million costs of the construction projects is found to be 19.721, while the “B” constant description of how the time output is affected by the size of the construction project when its cost is measured constant is found to be 0.504. Hence, the final equation showing the relationship between cost and time is given below.

$$T = 19.721\ C^{0.504} \quad (5)$$

The validation of the equation by R^2 value is estimated to be 0.76. This shows it to be reasonably suitable to utilize this equation for the prediction of the time for the construction projects under the Hyderabad Development Package, Pakistan. Whereas, the results of the second validation technique MAPE test has been shown. (see Table 3)

Table 3
MAPE Validation Results

S. No.	Actual Time	Predicted Time	MAPE	Remarks	S. No.	Actual Time	Predicted Time	MAPE	Remarks
1	400	388.7245	-2.81		16	560	561.2522	0.22	
2	210	214.0217	1.91		17	250	280.7071	12.28	NA
3	410	398.5005	-2.80		18	580	534.5553	-7.83	
4	510	461.3312	-9.54		19	540	563.6074	4.37	
5	290	325.7273	12.31	NA	20	540	541.1758	0.21	
6	230	236.9778	3.03		21	365	365.9547	0.26	
7	480	505.9846	5.83		22	270	286.4743	6.10	
8	420	413.0824	-1.64		23	520	500.8428	-3.68	
9	410	405.505	-1.09		24	390	392.0408	0.52	
10	590	594.4537	0.75		25	240	266.5577	11.06	NA
11	530	519.9107	-1.90		26	420	393.8583	-6.22	
12	610	620.8141	1.77		27	300	311.6949	3.89	
13	560	532.7282	-4.86		28	460	434.8172	-5.47	
14	440	420.9924	-4.31		29	150	142.4003	-8.39	
15	490	451.5121	-7.85		30	610	620.8141	1.77	

MAPE accepts the variation in the result of up to 10% (Rob J. Hyndman, 2006). The table indicates that three of the predictions exceed the limit of ± 10% and therefore can not be considered as satisfactory whilst the remaining forecasts are in an acceptable limit. The overall variation in the percentage of the predicted duration is ± 10% in total, which is quite satisfactory as per MAPE theorem.

6. Conclusions

The study results concluded that there exists a substantial relationship between the time and cost of construction projects in Pakistan using the BTC model but limited to tested data nature projects. The projects nature includes rehabilitation of drains, construction of local roads and various district level development project. The time cost model generated for these projects is adjusted to the square value R of 0.85 and MAPE ± 6.66%. Similar, time-cost relation has been perceived for Works and Services department of Pakistan, where the model generated for these projects is adjusted to the square value R of 0.76 and MAPE ± 10%. Alike other two, time-cost relation has been observed for the Hyderabad Development Package, Pakistan where the model generated for these projects is adjusted to the square value R of 0.76 and MAPE ± 10%.

Winning projects through bidding requires a highly qualified and professional approach. The adoption of the appropriate acquisition strategy to adapt to the circumstances has a vital role in ensuring the success of the project. Realistic project time is one of the key elements necessary for the preparation of the tender. The research successfully validates the time-cost relationship model developed by Bromilow in the construction

industry of Pakistan. As a result, three different mathematical equations were developed using a linear regression model.

These mathematical equations will supplement contractors in decision making as they equate the results obtained by these calculations with the time provided by the client in the tender phase. Entrepreneurs can extend this model by developing a database on these models for other projects in this industry at the provincial and national levels. This approach is based on the entrepreneur's historical data, which is more practical, concrete, and reliable than the subjective methods currently used based on experience and intuitions.

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Conflict of Interest

There is no conflict of interest for this research work and there are no financial liabilities and claims from any researcher or institute of this work.

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