

Assessing the Suitability of Bromilow Time-Cost (BTC) Model to Predict Project Time on Road Construction Projects in Botswana

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Abstract

The construction industry researchers have still found the Bromilow Time-Cost performance model given by $T = KC^B$ very relevant to today's construction processes. The only aspects that change in the model are the coefficient of the equation K, and the power of the cost B. This suggests that the equation characteristics only change with the type of project and the environment in which the project was executed. The model helps to forecast the duration of a project using the estimated final cost of the project. A fast estimate of construction time in the early phase of a project helps the contractor in avoiding time and cost overruns that might lead to dispute and possibly litigation. The motivation for this research was derived from the above assertions. Data for formulating the Bromilow model for road construction projects were collected from a sample of 54 road projects executed by the Botswana Department of Roads. Analysis showed that the Bromilow time-cost performance model for road construction project in Botswana is given by:

$$T = 14.11116C^{0.155488}$$

With $R^2 = 0.283266$ and adjusted $R^2 = 0.269483$. Even though the R^2 and the adjusted R^2 were considered a good fit for the data and the R^2 was within the range of what was found in the previous studies around the world which is between 0.205 and 0.850, the model may not provide a good base in Botswana for estimating the duration of a project at the early life when the early cost is known. It is recommended that data on recently completed projects be provided for in-depth analysis of the influence of variables such as funding, payment, rework, change orders, and many other agents of time-overruns might have contributed to project time in the Botswana construction industry.

Keywords: suitability, Bromilow's model, project time, road construction projects, Botswana

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1. Introduction

In general, the Botswana construction sectors can be roughly categorized into real estate (housing, industrial parks, plants, office, malls, hotels) and infrastructure comprising roads, rail, bridges, airports, hospitals, schools, and universities (Gorgenlander, 2011). The sector strives for steady growth on account of urbanization, economic development and people's rising need for improved quality of living. The construction industry is a complex environment in which each organization is faced with numerous opportunities and threats (Walker, 1995). Higher construction costs have been the concern on projects undertaken for the government of Botswana over a period of time. The majority of the projects that have been delivered were either delayed in terms of completion time or exceeded the budgeted project amount. This has an effect on the development budget for government and leads to reallocation of the scarce financial resources to projects that have exceeded their budgeted amounts. It is therefore important to identify the main dominating factors leading to high construction costs so that efforts can be put in place on these factors in order to reduce construction costs in Botswana.

The aim of the study was to find out the factors contributing to construction cost in Botswana and the associated objectives were to: (i) identify the main factors affecting construction costs in Botswana; (ii) determine the severity rank of each cost factors; (iii) suggest solutions that could minimize construction costs in Botswana.

2. The Construction Industry in Botswana

The construction industry in Botswana is an important sector of the economy contributing about 5.3% to the GDP (Adeyemi and Masalila, 2016); and the third largest employer of labour after Mining and Agriculture industries. The major client of the industry is government. Despite its importance in the socio-economic growth of Botswana, the industry is bedeviled with project failures manifesting as time and cost overruns across projects. Chimwaso (2000) in his research concluded that 70% of Botswana projects do incur time and cost overruns. Ever since this research output, there has been strings of headlines reporting project failure in the country with many blamed on irrevocable use of low-bid system and very slow application of best value procurement.

The major financier of road construction projects in Botswana in the Botswana Government through the Ministry of Works and Transport represented by the Department of Roads. A number of foreign funding agencies have been involved in road project, studies and technical assistance. Contributions have been received from AA, ADB, ADF, BADEA, CIDA, DANIDA, EEC, EDF, IBRD, IDA, Kwf, Kuwait, NORAD, ODA, OPEC, UNCDF

and USAID and some of the projects that are externally funded are still ongoing. The Botswana Roads Department uses competitive tendering as well as selective bidding for some other specialist mega projects. The criteria for selection of contractors as specified in the tender documents for construction include the following:

- Competence and integrity
- Past performance of the contractor and its reputation in terms of similar jobs (track record)
- The personnel strength of the contractor, its financial status and its ability to co-finance projects.
- The contractor's scheduled time of completion and final tender price.

The contractual arrangement is as shown on Figure 1 below. The client first appoints the consulting Engineers to advice and design on a variety of specialist works, e.g. structural, civil works and pavement design. Consultants are also engaged to provide a site team during construction to ensure that the project is kept within cost and complies with the design. The principal contractor is employed by the client on the advice of the engineer by nomination or competitive tendering. They are required to administer the construction programme within the Engineer's direction. A domestic subcontractor is employed by the principal contractor to assist with the general construction or installation, e.g. bricklaying, fencing, etc.

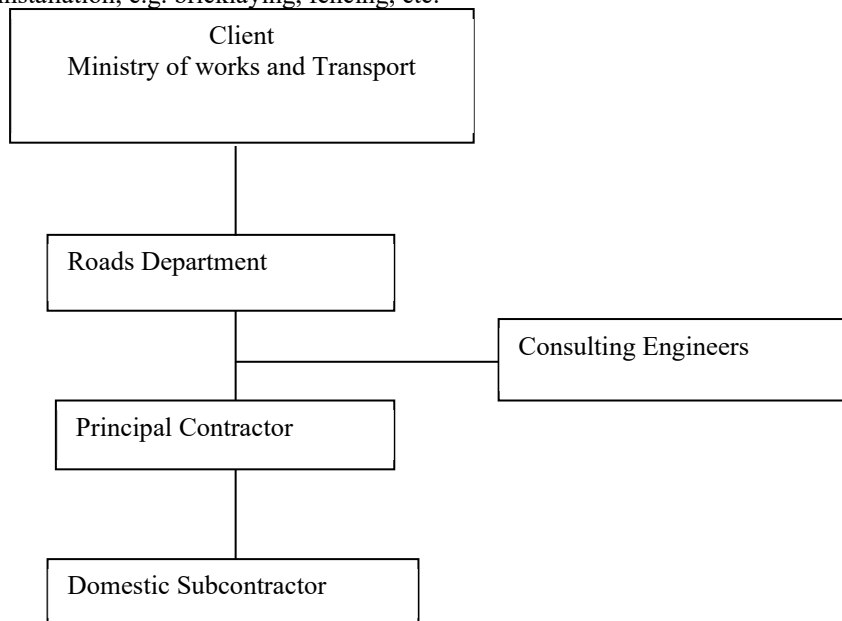


Figure1: Contractual Arrangement in the Construction of Roads in Botswana
Source Adeyemi and Segwabe (2016)

The relative high resource commitment by the government of Botswana to the construction of road projects has been highlighted in the Department of Roads website, (www.roads.gov.bw); during the years 1966 to 1986 more than P260 million has been invested in new road infrastructure. During the National Development Plan (NDP) 7, for the period from 1991 to 1997 P870 746 559.00 was spent for the development of the network. During the National Development Plan 8, for the period from 1997 to 2003 P2 661 274 384.00 was spent. For the period from 2003 to 2009 the estimated amount was P2467 660 000.00.

Despite government sincere efforts to provide adequate road infrastructure for the country, the proposition is often stalled by the low-bid-system with its associated corrupt system. For example, Adeyemi and Segwabe (2016) stated that out of the 31 road construction projects that were completed between 1996 to 2005 by the Department of Roads, only 6.5% of the projects were completed within the scheduled completion dates and 32% were completed within budget. These indicate that there are serious problems within the construction industry in Botswana most especially on road project delivery. Adding to this is the inadequacy of cost prediction at the early stage of the project. This is where Bromilow Time Cost (BTC) is useful.

3. Methodology

This research made use of purely secondary data collected from the archival documents of the Department of Roads, Gaborone, Botswana. The data consists of initial contract cost of each project and the actual cost on one hand, and the initial contract duration and the corresponding actual duration on the other. A total of 54 projects whose details were complete were included in the analysis. All the projects were executed between the years 1997 and 2010. Bromilow time-cost model (Equation 1) was used to quantitatively provide the construction time on 54 Roads Department projects. construction projects (Table 1) using the least square regression analysis. The constant K and B were calculated through the use of Statistical Package for Social Science (SPSS).

Table 1. Time and Cost Performance of Roads Department Projects

S/No	Initial Duration (Months)	Actual Duration (Months)	Initial Cost (Million BWP*)	Actual Cost (Million BWP*)	S/No	Initial Duration (Months)	Actual Duration (Months)	Initial Cost (Million BWP*)	Actual Cost (Million BWP*)
1	11	24	12.194	13.6	28	20	27	54.24	69.63
2	18	28	59.02	61.859	29	24	33	151.446	143.203
3	12	8	78.558	78.558	30	9	15	4.394	3.85
4	15	19	49.9	63.7	31	13	16	12.506	10.113
5	18	23	58.9	65.262	32	20	28	57.5	75
6	22	20	98	102.99	33	8	10	3.8	4.047
7	10	17	25.2	27	34	20	35	99.4	102.957
8	16	18	17.87	18.829	35	20	26	98.1	104
9	18	26	45.7	47.44	36	17	24	89.39	94.513
10	17	19	21.3	25.122	37	8	16	4.94	4.94
11	15	19	13.565	13.503	38	6.7	7	6.88	6.785
12	13	28	6.844	6.864	39	13	11	17.028	14.424
13	12.5	31	7.633	8.594	40	20	39	59.87	75.023
14	12.5	20	8.98	9.877	41	20	26	40.49	53.3
15	24	26	31.9	48.349	42	16	18	41.187	47.155
16	19	24	61.9	71.02	43	10	16	5.411	5.164
17	24	27	85.6	108.266	44	10	15	6.067	5.311
18	14	15	16.82	16.155	45	12	18	12.992	13.659
19	12	46	8.09	7.571	46	24	27	386	415
20	14	15	10.45	10.245	47	24	27	272	332
21	12	15	4.91	6.031	48	30	44	536	400
22	14	37	11.42	12.745	49	30	51	381.6	438.8
23	13	38	3.31	4.164	50	24	41	400	609
24	13	32	3.542	5.567	51	18	28	186	198
25	18	33	44.3	54.756	52	12	14	23.46	24.46
26	12	24	9.711	8.134	53	30	48	200.7	228.7
27	12	18	5.86	5.236	54	30	34	146.655	160.269

*10 BWP (Botswana Pula) ≈ 1USD

4. Analyses of Results and Discussion

Table 2 shows the SPSS details for calculating K and B for the 54 projects studied. Convergence for the least square process was achieved after six iterations.

Table 2: Calculated constants K and B using the least square method

	Coefficient	Std. Error	t-Statistic	Probability
K	14.11116	2.023719	6.972887	0.0000
B	0.155488	0.032940	4.720341	0.0000
T = 14.11116C ^{0.155488}				
R-squared	0.283266	Mean dependent variable	24.88889	
Adjusted R-squared	0.269483	S.D dependent variable	10.22883	
S.E of regression	8.742611	Akaike info criterion	7.210629	
Sum squared residual	3974.529	Schwarz criterion	7.284295	
Log likelihood	-192.6870	Hannan-Quinn criteria	7.239039	
Durbin-Watson stat	1.534876			

R-squared is a statistical measure in percentage of the variability of the response data around its mean. R-squared is always between 0 and 100% where:

- 0% indicates that the model explains none of the variability of the response data around its mean.
- 100% indicates that the model explains all the variability of the response data around its mean. In general, the higher the R-squared, the better the model fits the data.

From Table 2, the Bromilow time-cost relationship for the 54 roads projects is as given in equation 2.

$$T = 14.1111C^{0.1555} \dots \dots \dots (2)$$

Comparative results of similar studies around the world are as presented in Table 3.

Table 3: Bromilow's Time–Cost Model for Some Studies Around the World

Researcher(s)	Country of Research	Equation
Bromilow (1969)	Australia	$T = 211C^{0.3}$ (Public) $T = 156C^{0.3}$ (Private)
Bromilow (1974)	Australia	$T = 313C^{0.3}$
Chan (1991)	Hong Kong	$T = 152C^{0.29}$ (Unknown)
Kaka and Price (1991)	United Kingdom	$T = 398C^{0.32}$ (Public) $T = 274C^{0.21}$ (Private)
Yeong (1994)	Australia	$T = 287C^{0.237}$ (Public) $T = 161C^{0.367}$ (Private)
Yeong (1994)	Malaysia	$T = 269C^{0.215}$ (public and Private) $T = 518C^{0.352}$ (Public)
Kumaraswamy and Chan (1995)	Hong Kong	$T = 216.3C^{0.253}$ (Public) $T = 250C^{0.215}$ (Private)
	United Kingdom	$T = 486.7C^{0.205}$ (Public)
Mak <i>et al.</i> (2000)	Australia	$T = 131C^{0.131}$ (All types of project)
Ng <i>et al.</i> (2001)	Australia	$T = 130C^{0.310}$ (Public & private)
Chan (2001)	Malaysia	$T = 269C^{0.315}$ (Public)
Choudhry <i>et al.</i> (2002)	Bangladesh	$T = 149C^{0.27}$ (Private)
Endut <i>et al.</i> (2006)	Malaysia	$T = 303C^{0.157}$ (Public)
Ogunsemi and Jagboro (2006)	Nigeria	$T = 69C^{0.255}$ (Public)
Hoffman <i>et al.</i> (2007)	USA	$T = 26.8C^{0.202}$
Zujo and Car-Pusic (2008)	Bosnia and Herzegovina.	$T = 79C^{0.41}$ (Public)
Car-Pusic and Miladen (2009)	Croatia	$T = 88C^{0.54}$
	Bosnia Herzegovina	$T = 70C^{0.52}$ (New Construction)
Le- Hoai <i>et al.</i> (2009)	Vietnam	$T = 94C^{0.338}$
	South Korea	$T = 341C^{0.175}$
Ameyaw <i>et al.</i> (2012)	Ghana	$T = 3.17C^{0.378}$ (Public)
Rahman <i>et al.</i> (2014)	Bangladesh	$T = 156C^{0.36}$ (Private)
Mačková and Baskova (2014)	Slovakia	$T = 384C^{0.263}$ (Private)
Adeyemi and Masalila (2016)	Botswana	$T = 01.18C^{0.362}$ (Gaborone City Council)
Adeyemi and Motlakase (2020)	Botswana	$T = 14.111C^{0.156}$ (Roads Department)

In this study, R-Square is 0.283266. Even though the R^2 compares favourably with what is found in literature that R-squared is usually between 0.205 to 0.850 when BTC are compared among countries (Rahman *et al.* 2014), this value is rather weak to predict the project time (T).

5. Conclusion

Data reflecting duration and cost of 54 road construction projects in Botswana were used to construct a Bromilow time- cost model. The model was $T = 14.111C^{0.156}$ with $R^2 = 0.283266$ and adjusted $R^2 = 0.269483$. The R^2 and adjusted R^2 were considered a good fit for the data and the R^2 was within the range of what was found in the previous studies around the world which is between 0.205 and 0.850. However, this model may not provide a good base in Botswana for estimating the duration of a project at the early life when the early cost is known. It is recommended that data on recently completed projects be provided for in-depth analysis of the influence of cost variables (Adeyemi and Nduna,2019) might have affected project time in the Botswana construction industry

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Appendix

List of Abbreviations

ADB	African Development Bank.
BADEA	Arab Bank for Economic Development in Africa
CIDA	Canadian International Development Agency
DANIDA	Danish International Development Agency
EEC	European Economic Community
IBRD	International Bank for reconstruction and Development
NORAD	North American Aerospace Defense Command
OPEC	Organization of Petroleum Exporting Countries
UNCDF	United Nations Capital Development Fund
USAID	United States Agency for International Development