International Journal of Engineering and Management Research
e-ISSN: 2250-0758 | p-ISSN: 2394-6962
https://ijemr.vandanapublications.com

Peer Reviewed & Refereed Journal
Volume-14, Issue-1 (February 2024)
https://doi.org/10.5281/zenodo.10697589

Development of a Time-Cost Model for Construction Projects in Federal Polytechnic of Oil and Gas, Nigeria

Kenneth Miebaka Oba[1] and Dareme Constantine Oloko[2]
[1]Department of Civil Engineering, Rivers State University, Port Harcourt, NIGERIA
[2]Department of Architectural Technology, Federal Polytechnic of Oil and Gas, Bonny, NIGERIA

[1]Corresponding Author: kenneth.oba@ust.edu.ng

Received: 15-01-2024 Revised: 04-2-2024 Accepted: 21-02-2024

ABSTRACT

Tertiary institutions in Nigeria are usually faced with the problem of completing building projects within the scheduled durations and budgeted costs. In this study, 8 building construction projects completed in the Federal Polytechnic of Oil and Gas were analysed between the years 2014 and 2023. A non-linear regression time-cost model was developed based on the Bromilow's Time-Cost (BTC) model. The results show that it would take 1858.3 working days to complete the construction of a building in a Nigerian tertiary institution for every one million Australian Dollars. Predictions were made for construction durations and construction costs with the formulated model. The model was found to be adequate and fit, with an R2 value of 0.8218. This also indicates that the BTC model applies to tertiary institution building construction projects in Nigeria.

***Keywords*—** Bonny, Bromilow, Buildings, Tertiary Institutions, Time-Cost Model

I. INTRODUCTION

It is common knowledge that time, cost, and quality are the most important performance measurement tools in construction projects. Most times, the cost and time are of more critical interest [1], [2], [3] than any other tool. In the same thinking, several studies [4], [5], [6] have been done on the time, cost, and quality performances of construction projects in Nigeria. All of these were in line with addressing the issues of delays and cost overruns in construction projects.

The town, Bonny is a major Island where oil and gas activities take place in Nigeria. It is located in Rivers State, near the Atlantic Ocean. It is one of the highest revenue-generating communities in Nigeria. The town is located in the Niger Delta region of the south-south geo-political zone of Nigeria. The Island also has a rich social and cultural heritage. It is also the location of notable establishments such as the Nigerian Liquified Natural Gas (NLNG), and the Federal Polytechnic of Oil and Gas. For these reasons, several people travel from different parts of Nigeria and the world to study, work, live, and do business in Bonny.

The Federal Polytechnic of Oil and Gas, Bonny, was established in 2013 to enable adequate formal and academic training of persons to man the high demand for skilled labour in the oil-rich Island. It is a small Polytechnic that is gradually growing in terms of personnel and infrastructure. To this note, several buildings have been constructed to satisfy the required status of a world-class Polytechnic.

Cash flow from the clients, weather, budgets, procurement methods, favouritism, nepotism, and inflation are some of the likely causes of cost overruns and delays in construction projects in Nigeria. Recently, [7] researched time and cost for building construction projects in the city of Port Harcourt. There is however limited research on quality, time, and cost performances related to construction in tertiary institutions in Nigeria. This research aims to solve the problem of delays and cost overruns in the construction of buildings in tertiary institutions, by arming the researcher or construction practitioner with a model that can predict completion times and contract sums. The Bromilow's Time-Cost (BTC) model was adopted for this study.

The study of cost overruns and delays in construction projects has seen several dimensions, some of which have resulted in mathematical models. Most of such models were regression models. [8] was the first researcher to study construction performance in terms of time and cost, leading to mathematical modelling. His study was performed on 303 building construction projects completed in Australia between the years 1964 and 1967. He eventually developed a non-linear power regression model in eq. (1), widely referred to as the Bromilow's Time-Cost model (BTC). He also generated the curve in

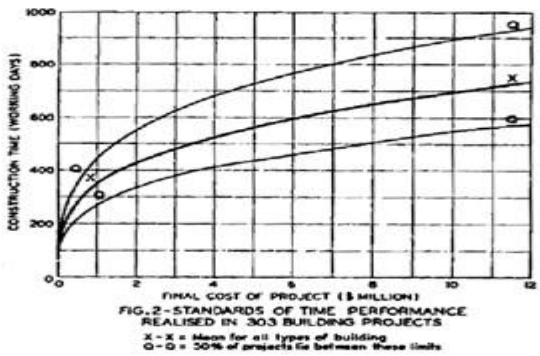

Figure 1: from the same study.

$$\mathrm{B} = \frac{ln\mathrm{T}}{ln\mathrm{C}}$$

Figure 1: Project Cost vs Construction Time [8]

$$\boldsymbol{T = KC^B} \quad (1)$$

Where T = the time or duration of project in working days

C = the Cost of the project per million Australian dollar, adjusted to constant labour and material prices

K = a constant of the project time performance

B = a constant of the sensitivity of the time performance to cost level.

In that study, [8] analysed the regression model and arrived at K and B to be 211 and 0.3 respectively. Several other researchers have since developed similar values of K and B as shown in Table 1. [8] also discovered that the project duration is highly correlated with the size of project in terms of cost. Several other researches [5], [7], [9], [10], [11], [12], [13], [14], [15], [16] have affirmed this fact. However, some researchers have criticized the Bromilow's time-cost model in several aspects. For instance, [9], [10] argued that when the model is in a linear form, '*ln* K' in eq. (3) has little or no predictive ability, and should therefore be excluded in the model.

$$ln\,\mathrm{T} = ln(\mathrm{KC^B}) \quad (2)$$

$$ln\,\mathrm{T} = ln\,\mathrm{K} + ln\mathrm{C^B}$$
$$ln\,\mathrm{T} = ln\,\mathrm{K} + \mathrm{B}ln\mathrm{C} \quad (3)$$

Hence, [9], [10] modified the model to eq. (4) thus:

(4)

[9] also found from their study that there was no significant difference between public and private sector buildings. They however arrived at a model for non-industrial buildings (which included residential and educational buildings) and another for industrial buildings using the BTC approach. A similar study conducted by [12] showed that the BTC model is not applicable to Ghanaian building construction projects as indicated by its R^2 values of 0.684, 0.463, 0.399, and 0.378 for buildings of office, classroom, residential, and combined data respectively. Similarly, [14] affirmed that the BTC model is not applicable to buildings in Nigeria, as indicated by its weak R^2 value of 0.205. They rather suggested the use of piecewise model, which gave an R^2 value of 0.765. In a similar study carried out by [5] the BTC model was found to be not practicable in road construction projects in Nigerian, as it indicates a weak predictive ability with Mean Absolute Percentage Error (MAPE) of 19%, and an R^2 value of 0.549. However, [11] affirmed the various versions of the calibration of the BTC model, stating that the criticisms from [9], [10] are based on Australian data, but are inconsistent with literature and their own research work. Similarly, [13] also affirmed the applicability of the BTC model to residential buildings in Slovakia, as it resulted in an R^2 value of 0.808 and a MAPE of 12.3%, which indicates a strong predictive ability. A recent study by [7] also affirm and confirm the efficacy of the BTC model when applied to residential buildings in Port Harcourt, Nigeria.

Table 1: K and B values from different studies

Researcher	Country	Sector of construction	Type	Model	K	B
[8]	Australia	Public	Building	$T = 211C^{0.3}$	211	0.3
		Private	Building	$T = 156C^{0.3}$	156	0.3
		Overall	Building	$T = 177C^{0.3}$	177	0.3
[9]	Australia	Public	Building	$T = 129C^{0.32}$	129	0.32
		Private	Building	$T = 132C^{0.3}$	132	0.3
		Overall	Building	$T = 131C^{0.31}$	131	0.31
[16]	Vietnam	Public	Building	$T = 98.1C^{0.343}$	98.1	0.343
		Private	Building	$T = 87.2C^{0.348}$	87.2	0.348
		Overall	Building	$T = 93.6C^{0.338}$	93.6	0.338
[5]	Nigeria	Public	Highway	$T = 2.8C^{0.5352}$	2.8	0.5352
[12]	Ghana	Office	Building	$T = 344.586C^{0.684}$	344.586	0.684
		Residential	Building	$T = 512.28C^{0.463}$	512.28	0.463
		Classroom	Building	$T = 2.807C^{0.399}$	2.807	0.399
		Combined	Building	$T = 3.17C^{0.378}$	3.17	0.378
[15]	Poland	Public	Highway	$T = 3.342C^{0.4649}$	3.342	0.4649
[14]	Nigeria	Private	Building	$T = 63C^{0.262}$	63	0.262
[7]	Nigeria	Private	Building	$T = 2289.2C^{0.624}$	22289.2	0.624

Since 1969 when Bromilow first developed the time-cost model, several other mathematical models have emerged and proven to be effective. Some are based on the BTC model, while others are based on other mathematical concepts [16], [17], [18], [19], [20], [21]. [15] proved that the logarithm linear form of the BTC in eq. (3) is the most efficient time-cost model for the construction industry in Poland as compared to two other time-cost models. [18] recently conducted a study on sustainable and conventional university buildings in North America, using a multiple linear regression (MLR) model. The model was found to be adequate and fit based on its R2 value of 0.874 and its t-test and F-test indicating no significant difference between the actual and predicted costs of construction. Similarly, [22] also predicted the cost of construction of communication towers in Iraq, using the MLR model, resulting in 0.984 and 9.891% as the R2 value and Mean Average Percentage Error (MAPE) respectively, which indicates the model to be fit. [19] developed some models which showed that, among the models developed, the MLR model gave a better R2 value of 99.44%, compared to 90.9%, 96.94%, and 86.14% for the Artificial Neural Network (ANN), Trend line, and Factor based models respectively. In another study, [23] confirmed that the Support Vector Machine (SVM) model resulted in a more accurate prediction than the MLR and BTC models.

II. METHODOLOGY

The study was conducted by collecting data consisting of construction projects executed by the physical planning unit of the Federal Polytechnic of Oil and Gas, Bonny. The data spans between projects commencing from the years 2014 and 2020. This came to a total of eight completed projects between 2014 and 2023. From eq. (1), the BTC model was developed. The model predicted results were tested, using a two-tailed statistical t-test.

III. RESULTS AND DISCUSSIONS

The data in Table 2 show the durations and cost of each of the eight projects.

Table 2: Details of Costs and Durations of Construction Projects

S/N	Title Of Project	Approved Costs (₦)	Costs (Aus$1,000,000)	Durations (Days)
1	Construction Of School of Applied Sciences Lecture Theatre	226,998,500.00	0.247	999
2	Construction of School of Engineering Lecture Theatre	227,100,120.75	0.247	923
3	Construction of Polytechnic Library	227,120,000.00	0.247	956
4	Construction of one Storey School of Engineering Academic Building	179,861,867.38	0.196	776
5	Construction of One Storey Offices for School of Engineering	166,360,203.85	0.181	889
6	Construction of One Storey School of Applied Sciences Academic Building	179,861,867.38	0.196	876
7	Construction of One Storey Offices for School of Applied Sciences	166,266,213.38	0.181	768
8	Construction of Administrative Building	330,336,424.28	0.360	1123

From the data in Table 2, the Bromilow's Time-Cost model for building construction projects in the Federal Polytechnic of Oil and Gas, Bonny, was developed using Microsoft Excel, as presented in eq. (5). It is also shown in its graphical form in Fig. 2. The Aus$ as at February 2024 was ₦918.77.

$$T = 1858.3C^{0.482} \quad (5)$$

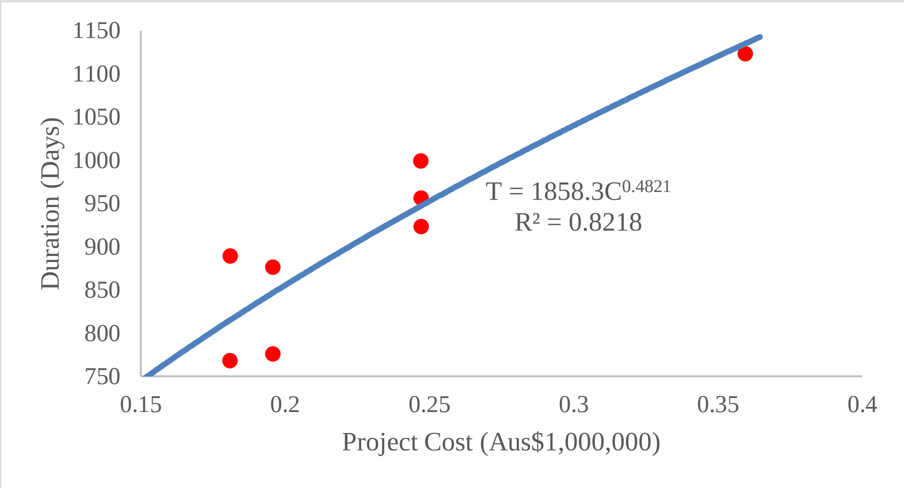

Figure 2: The BTC model for building Projects in Federal Polytechnic of Oil and Gas

The formulated model was used to predict the costs and durations for the projects as shown in Table 3 with an R^2 of 0.8218.

Table 3: Details of Costs and Durations of Building Projects

S/N	TITLE OF PROJECT	ACTUAL COSTS (Aus$1,000,000)	PREDICTED COSTS (Aus$1,000,000)	ACTUAL DURATIONS (DAYS)	PREDICTED DURATIONS (DAYS)
1	Construction of School of Applied Sciences Lecture Theatre	0.247	0.276	999	947
2	Construction of School of Engineering Lecture Theatre	0.247	0.234	923	947
3	Construction of Polytechnic Library	0.247	0.252	956	947
4	Construction of One Storey School of Engineering Academic Building	0.196	0.163	776	847
5	Construction of One Storey Offices for School of Engineering	0.181	0.217	889	815
6	Construction of One Storey School of Applied Sciences Academic Building	0.196	0.210	876	847
7	Construction of One Storey Offices for School of Applied Sciences	0.181	0.160	768	815
8	Construction of Administrative Building	0.360	0.352	1123	1135

Table 4 shows the two-tailed student t-test results for the actual and predicted durations and costs. The results indicate that the model is adequate and fit.

Table 4: Details of Costs and Durations of Building Projects

t-Test: Paired Two Sample for Means			t-Test: Paired Two Sample for Means		
	T_{actual}	$T_{predicted}$		C_{actual}	$C_{predicted}$
Mean	913.75	912.65	Mean	0.2318	0.2329
Variance	13597.07	11526.42	Variance	0.00354	0.00390
Observations	8	8	Observations	8	8
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
df	7		df	7	
t Stat	0.063319		t Stat	-0.13238	
P(T<=t) one-tail	0.475641		P(T<=t) one-tail	0.449204	
t Critical one-tail	1.8946		t Critical one-tail	1.89458	
P(T<=t) two-tail	0.9513		P(T<=t) two-tail	0.8984	
t Critical two-tail	2.3643		t Critical two-tail	2.3643	
Correlation	R^2	R^2 (adj.)	Correlation	R^2	R^2 (adj.)
	0.8218	0.7921		0.8529	0.8284

IV. CONCLUSION

The data obtained from the Federal Polytechnic of Oil and Gas in Bonny has resulted in the formulation of a model that is based on the Bromilow's Time-Cost model. The model showed that it would take 1858.3 working days to complete the construction of a building in a tertiary institution in Nigeria, for every Aus$1 million. This is way higher than most other results obtained by previous researchers in other parts of the world. However, the said value is lower than that obtained by [7]. However, the BTC model in this study was found to be fit and adequate, as it passed the two-tailed student t-test with an R^2 value of 82.18%. In contrast with [5] and [14], the model is applicable in the Nigerian construction industry, especially in tertiary institutional buildings. The problems of cost overrun and delays will be well solved by the use of the model formulated from this study. Further studies are recommended to improve on the applicability of the model in the Nigerian construction industry.

REFERENCES

[1] J. Bennette & T. Grile. (1990). *Procurement systems for buildings," in quantity surveying techniques: New directions, P. Brandon, Ed.*, Oxford: Blackwell Scientific Publications.
[2] D. Lowe & M. Skitmore, (1994). Experiential learning in cost estimating. *Construction Management and Economics, 12*(5), 423–431.
[3] O. Durson & C. Stoy. (2011). Time-cost relationship of building projects: Statistical adequacy of categorisation with respect to project location. *Construction Management and Economics, 29*(1), 97–106.
[4] K. M. Oba. (2018). Cost, time, and quality factors: A case study of the rivers monorail construction project. *IOSR Journal of Mechanical and Civil Engineering*, 15(1), 12–17.
[5] B. S. Waziri & N. Yusuf. (2014). Application of bromilow's time-cost (BTC) model to highway projects in Nigeria. *Arid Zone Journal of Engineering, Technology and Environment, 10*(1), 1–11.
[6] B. O. Ganiyu & I. K. Zubairu. (2010). Project cost prediction model using principal component regression for public building projects in Nigeria. *Journal of Building Performance, 1*(1), 21–28.
[7] K. M. Oba & S. E. George. (2022). Development of a time-cost model for private residential building projects in port harcourt. *Journal of Newviews in Engineering and Technology, 4*(1), 57–65. [Online]. Available at: http://www.rsujnet.org/index.php/publications/2022-edition.
[8] F. J. Bromilow. (1969). Contract time performance expectations and the reality. *Building Forum, 1*(3), 70–80.
[9] S. T. Ng, M. Mak, R. M. Skitmore & M. Varnam. (2001). The predictive ability of bromilow's time-cost model. *Construction Management and Economics*, *19*(2), 165–173. DOI: 10.1080/01446190150505090.
[10] M. Skitmore & T. Ng. (2001). Australian project time-cost analysis: Statistical analysis of intertemporal trends. *Construction Management and Economics, 19*(5), 455–458.
[11] R. Kenley. (2001). The predictive ability of bromilow's time-cost model: A comment. *Construction Management and Economics, vol. 19*(8), 759–764.
[12] C. Ameyaw, S. Mensah & Y. D. Arthur. (2012). Applicability of bromilow's time–cost model on building projects in Ghana In: *Procs 4th*

West Africa Built Environment Research (WABER) Conference, pp. 881–888.

[13] D. Mackova, M. Kozlovska, R. Baskova, M. Spisakova & K. Krajnikova. (2017). Construction-duration prediction model for residential buildings in slovak republic based on computer simulation. *International Journal of Applied Engineering Research*, *12*(13), 3590–3599.

[14] D. R. Ogunsemi & G. O. Jagboro. (2006). Time-cost model for building projects in Nigeria. *Construction Management and Economics, 24*(3), 253–258.

[15] Czarnigowska & A. Sobotka. (2013). Time-cost relationship for predicting construction duration. *Archives of Civil and Mechanical Engineering, 13*(4), 518–526.

[16] L. Le-hoai, Y. D. Lee & J. W. Cho. (2009). Construction of time - cost model for building projects in Vietnam. *Korean Journal of Construction Engineering and Management*, *10*(3), 130–138.

[17] A. A. Hammad, S. M. A. Ali, G. J. Sweis & A. Bashir. (2008). Prediction model for construction cost and duration in Jordan. *Jordan Journal of Civil Engineering, 2*(3), 250–266.

[18] O. S. Alshamrani. (2017). Construction cost prediction model for conventional and sustainable college buildings in North America. *Journal of Taibah University for Science, 11*(2), 315–323.

[19] H. A. Fidvi, R. R. Paliwal, A. S. Puttewar & K. N. Agrawal. Mathematical modeling to predict escalated project cost using artificial neural network with an application to cost of setting up thermal power plant. In: *International Conference on Advances in Engineering & Technology - 2014 (ICAET - 2014), IOSR Journal of Mechanical and Civil Engineering,* pp. 60–66.

[20] A. Purnus & C. Bodea. (2014). Correlation between time and cost in a quantitative risk analysis of construction project. In: *Creative Construction Confernce*, *Procedia Engineering*, pp. 436–445.

[21] R. C. Williams. (2008). *The development of mathematical models for preliminary prediction of highway construction duration*. (Ph.D Thesis, Faculty of Civil Engineering, Virginia Tech).

[22] F. M. S. Al-zwainy & N. T. Hadhal. (2016). building a mathematical model for predicting the cost of the communication towers projects using multifactor linear regression technique. *International Journal of Construction Engineerig and Management*, *5*(1), 25–29.

[23] S. Petruseva, V. Zileska-pancovska, V. Žujo & A. Brkan-Vejzović. (2017). construction costs forecasting: comparison of the accuracy of linear regression and support vector machine models. *Technical Gazette*, *24*(5), 1431–1438.

