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Development of a Time-Cost Model for Private Residential Building Projects in Port Harcourt, Nigeria

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ABSTRACT
Property developers in Port Harcourt are often faced with the challenge of completing residential building projects within the scheduled times and costs due to factors that include weather, inadequate cash inflow, government policies, and inflation. About 41 private residential building projects completed between the years 2000 and 2018 were surveyed with the aid of questionnaires, and it was found that the highest cause of both delay and cost overrun was inadequate cash flow. A non-linear regression time-cost model was formulated based on the Bromilow's Time-Cost (BTC) model and found that it takes 2289.2 working days to complete a private residential building project per million Australian Dollar. Predictions were made for construction durations (times) and construction costs with the derived model, which was found fit and adequate with an R^2 value of 0.6137. This indicates that the BTC model is applicable to private residential building projects in Port Harcourt.

KEYWORDS: Bromilow, Cost Overrun, Delay, Time-Cost Model, Residential Building, Port Harcourt

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1. INTRODUCTION
It is widely believed that the most critical parameters to measure construction performance are cost, time, and quality. In most cases, the time and cost turned out to be more of interest (Bennette & Grile, 1990; Durson & Stoy, 2011; Lowe & Skitmore, 1994). In line with these, several studies (Ganiyu & Zubairu, 2010; Oba, 2018; Waziri & Yusuf, 2014) have been carried out by different researchers on the cost, time, and quality performances of construction projects in Nigeria. All of these were in a bid to address the issues of time and cost overrun in construction projects. However, not much of such research were carried out for the city of Port Harcourt. Port Harcourt, being the capital city of Rivers state, is the oil and gas hub of Nigeria. It is one of the largest cities, and one of the highest revenue-generating cities in Nigeria. The city is in the Niger Delta region of the south-south geo-political zone of the country. It is also very rich in social and cultural heritage. As a result of these, several people migrate from different parts of the country and the world to the oil-rich city to work and live in it. This has continuously increased the population and the demand for residential buildings in the city.

In addition, a large portion of the city is constituted of rivers and lakes. This makes the city to have a high rainfall frequency and intensity. Property developers are sometimes faced with issues of time and cost overrun due to certain reasons such as cash flow from the clients, budgets, weather, procurement, inflation, nepotism, etc. This study was focused on private residential buildings that were constructed in Port Harcourt between the years 2000 and 2018, taking into consideration the issues that could cause delay or cost overrun. The study also applied the Bromilow's Time-Cost (BTC) model to the situation of time and cost overrun for such buildings in the city.

Projects experience delays when they run behind their original scheduled durations. Furthermore, cost overrun can occur when the project exceeds its budgeted cost. The study of delays and cost overrun in construction projects has witnessed several dimensions, some of which have resulted in scientific and mathematical modelling approaches. Most of such approaches were with the use of regression models. Bromilow (1969) was the first researcher that carried out thorough

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studies on time and cost related performance of construction projects that led to mathematical modelling. His study was on 303 building construction projects completed in Australia between 1964 and 1967 where he developed the non-linear power regression model in Equation (1) popularly known as the Bromilow's Time-Cost model (BTC). The curve in fig. 1 was also generated from the said study.

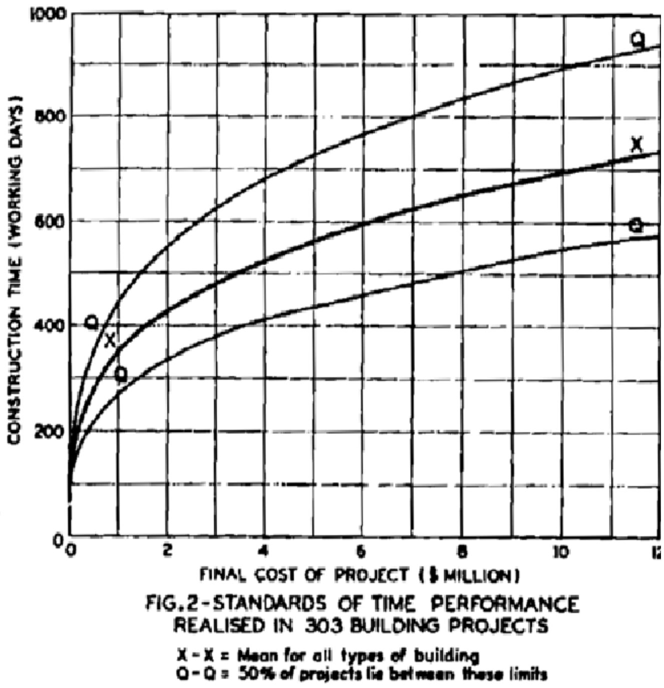

Fig. 1: Project Cost vs Construction Time
(Bromilow, 1969)

$$T = KC^B \quad (1)$$

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 the said study, Bromilow (1969) analysed the regression model and arrived at values of 211 and 0.3 for K and B respectively. Table 1 shows some values of K and B from various studies. Bromilow (1969) also discovered that the project duration is highly correlated with the project size in terms of cost. This fact has been widely proven to be true by several other studies especially by (Ameyaw *et al*., 2012; Czarnigowska & Sobotka, 2013; Kenley, 2001; Le-hoai *et al*., 2009; Mackova et al., 2017; Ng *et al*., 2001; Ogunsemi & Jagboro, 2006; Skitmore & Ng, 2001; Waziri & Yusuf, 2014). However, some researchers have criticised the model in various aspects. For instance, Ng *et al*. (2001), Skitmore and Ng (2001) argued that the model when linearized found '*ln* K' in Equation (3) to have little or no predictive ability, hence should be excluded in the model.

$$\ln T = \ln (KC^B) \quad (2)$$

$$\ln T = \ln K + \ln C^B$$

$$\ln T = \ln K + B \ln C \quad (3)$$

For this reason, Ng *et al*. (2001), Skitmore and Ng (2001) modified the model to Equation (4).

$$B = \frac{\ln T}{\ln C} \quad (4)$$

In their study, Ng *et al*. (2001) also found that there was no significant difference between public and private sector buildings. However, they arrived at a model for industrial buildings and another for non-industrial buildings (which included residential and educational buildings) using the BTC approach. A similar study carried out by Ameyaw *et al*. (2012) showed that the BTC model was not applicable to Ghanaian building construction projects as it gave low R^2 values of 0.684, 0.463, 0.399, and 0.378 for buildings of office, classroom, residential, and combined data respectively. Ogunsemi & Jagboro (2006) also affirmed that the BTC model cannot be applicable to buildings in Nigeria, as it resulted in a weak R^2 value of 0.205. They rather suggested the use of piecewise model which resulted in an R^2 value of 0.765. Similarly, Waziri and Yusuf (2014) also found that the BTC model is not practicable in the road construction aspect of the Nigerian context, as it resulted in a weak predictive ability with Mean Absolute Percentage Error (MAPE) of 19%, and an R^2 value of 0.549. However, in another study, Kenley (2001) upheld the various versions of the calibration of the model by Bromilow, pointing out that the criticisms from Ng *et al*. (2001), Skitmore and Ng (2001) although are based on Australian data, but are inconsistent with literature and their own work. Similarly, Mackova *et al*. (2017) also affirmed the applicability of the

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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 indicate a strong predictive ability.

The first model was developed by Bromilow in 1969 as stated earlier. Several other mathematical models have since then been developed and proven efficient. Some of such models are based on the BTC model, while others are not (Alshamrani, 2017; Fidvi *et al*., 2014; Hammad *et al*., 2008; Le-hoai et al., 2009; Purnus & Bodea, 2014; Williams, 2008). In fact, Czarnigowska and Sobotka (2013) even proved that the logarithm linear form of the BTC as in Equation (3) is the most efficient time-cost model for the construction industry in Poland as they compared it with two other time-cost models. Recently, Alshamrani (2017) carried out a study on conventional and sustainable university buildings in North America, using a multiple linear regression model (MLR). The model was found to be fit and adequate with an R^2 value of 0.874 and t- and F-tests showing no significant difference between the predicted and actual construction costs. In a similar study, Al-zwainy and Hadhal (2016) also used the MLR model to predict the cost of construction of communication towers in Iraq, which resulted in an R^2 value of 0.984 and a MAPE of 9.891%, indicating a very fit model. Some other time-cost models were formulated by Fidvi *et al*. (2014). The results from their study showed that the MLR model gave a better R^2 value of 99.44% as against 90.9%, 96.94%, and 86.14% for the Artificial Neural Network (ANN), Trend line, and Factor based models respectively. In a similar study, Petruseva *et al*. (2017) found that the Support Vector Machine (SVM) model gave a more accurate prediction than the BTC and the MLR models.

The objectives of this study are to conduct a questionnaire survey on residential building owners, analyse the data collected from the survey, and develop a BTC model from the collected data.

2. MATERIALS AND METHODS

The study was conducted by first sending questionnaires with structured questions to owners of completed private residential buildings in selected parts of the city of Port Harcourt. The buildings were between bungalows and one-storey buildings. These owners admitted that their buildings were completed between the years 2000 and 2018. A total of 100 questionnaires were delivered, but only 70 were retuned, out of which 29 were invalid due to incomplete information. The remaining 41 were used for the analysis. The BTC model was then formulated from Equation (1). A two-tailed statistical t-test was carried out on the results predicted from the model.

$$T = KC^B \quad (5)$$

3. RESULTS AND DISCUSSION

The results of the analysis shown in fig. 2 and fig. 3 express the causes of delays in completion of the projects and cost overrun respectively.

Based on the data above the Bromilow's Time-Cost model for private residential building projects in Port Harcourt was formulated using Microsoft Excel and is presented in Equation (6). The model is also visualized in fig. 4.

$$\boldsymbol{T = 2289.2C^{0.624}} \quad (6)$$

The model was used to predict the times (durations) and the costs as shown in Table 3 with an R^2 value of 0.6137.

In Table 4, the two-tailed student t-test results for the actual and predicted times (durations) and costs. The results show that the model is fit and adequate.

Table 1: Values of K and B from various studies

Researcher	Country	Sector of construction	Type	Model	K	B
Bromilow (1969)	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
Ng *et al.* (2001)	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
Le-hoai *et al.* (2009)	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
Waziri & Yusuf (2014)	Nigeria	Public	Highway	$T = 2.8C^{0.5352}$	2.8	0.5352
Ameyaw *et al.* (2012)	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
Czarnigowska & Sobotka (2013)	Poland	Public	Highway	$T = 3.342C^{0.4649}$	3.342	0.4649
Ogunsemi & Jagboro (2006)	Nigeria	Private	Building	$T = 63C^{0.262}$	63	0.262

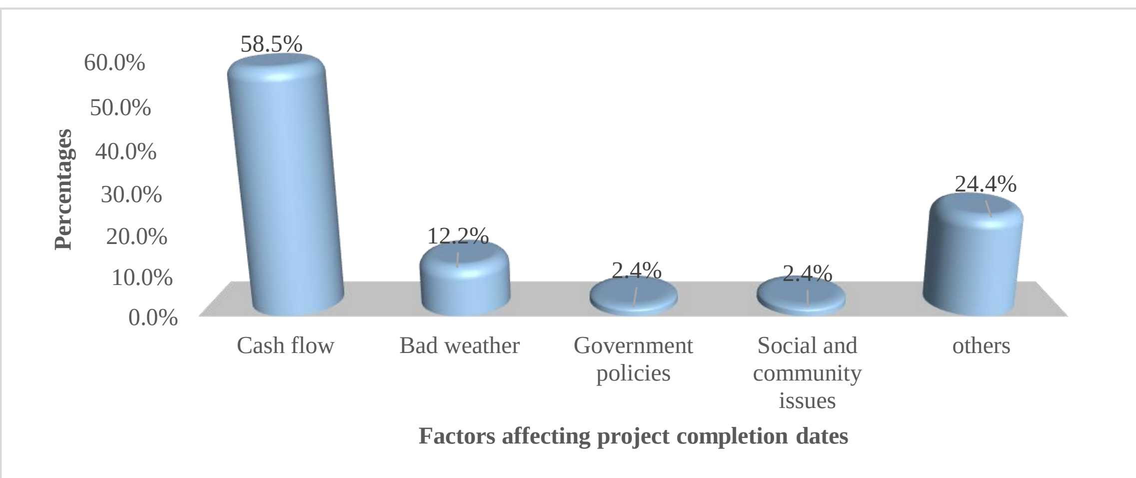

Fig. 2: Causes of delay in project completion time

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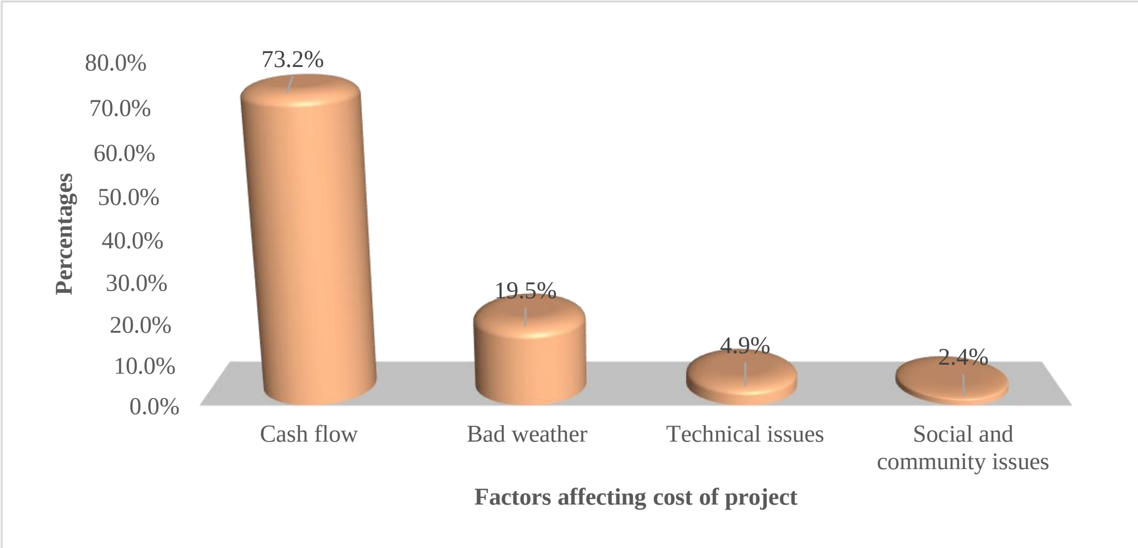

Fig. 3: Causes of cost overrun

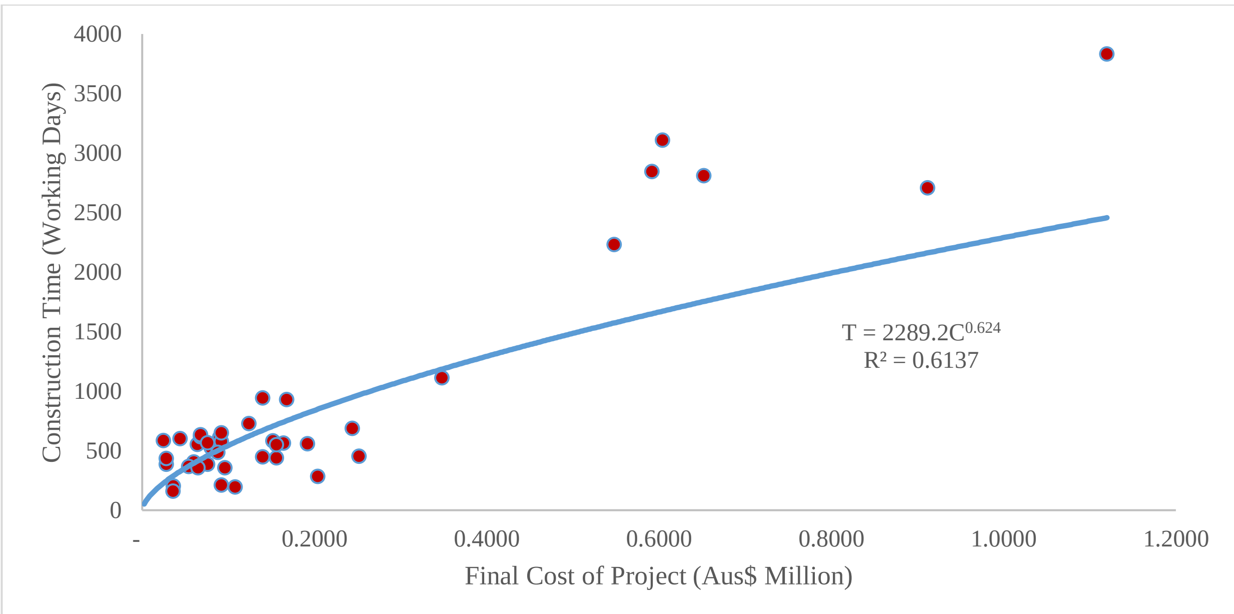

Fig. 4: The BTC model for Private Residential building Projects in Port Harcourt

The respondents' project details are shown in Table 2.

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Table 2: Details of Costs and Durations of Building Projects

S/N	Project title	Start date	Actual finish dates	Actual duration (days)	Contract sum (₦)		Contract sum (Aus$)		Contract sum (Aus$1million)	
					Original	Actual	Original	Actual	Original	Actual
1	Resid. Buildg. 1	27-Dec-16	22-Jun-18	387	15,000,000.00	19,000,000.00	60,000.00	76,000.00	0.0600	0.0760
2	Resid. Buildg. 2	5-Aug-01	10-Dec-03	612	20,000,000.00	22,500,000.00	80,000.00	90,000.00	0.0800	0.0900
3	Resid. Buildg. 3	11-Feb-98	12-May-00	586	4,750,000.00	6,235,000.00	19,000.00	24,940.00	0.0190	0.0249
4	Resid. Buildg. 4	5-Dec-93	4-Feb-96	565	33,330,000.00	41,000,000.00	133,320.00	164,000.00	0.1333	0.1640
5	Resid. Buildg. 5	6-Mar-14	20-Jul-15	358	20,000,000.00	24,000,000.00	80,000.00	96,000.00	0.0800	0.0960
6	Resid. Buildg. 6	1-Feb-17	21-Oct-18	448	22,000,000.00	35,000,000.00	88,000.00	140,000.00	0.0880	0.1400
7	Resid. Buildg. 7	2-Feb-17	15-Nov-17	204	8,000,000.00	9,100,000.00	32,000.00	36,400.00	0.0320	0.0364
8	Resid. Buildg. 8	10-Jan-17	19-Sep-18	441	30,000,000.00	39,000,000.00	120,000.00	156,000.00	0.1200	0.1560
9	Resid. Buildg. 9	6-Mar-08	22-Jul-18	2707	180,000,000.00	228,000,000.00	720,000.00	912,000.00	0.7200	0.9120
10	Resid. Buildg. 10	21-Sep-15	10-Apr-17	405	10,000,000.00	15,000,000.00	40,000.00	60,000.00	0.0400	0.0600
11	Resid. Buildg. 11	10-Oct-99	17-Jun-14	3831	250,000,000.00	280,000,000.00	1,000,000.00	1,120,000.00	1.0000	1.1200
12	Resid. Buildg. 12	25-Feb-11	11-Apr-13	554	15,000,000.00	16,000,000.00	60,000.00	64,000.00	0.0600	0.0640
13	Resid. Buildg. 13	15-Nov-04	21-Nov-06	526	16,000,000.00	20,000,000.00	64,000.00	80,000.00	0.0640	0.0800
14	Resid. Buildg. 14	19-Aug-13	12-Mar-17	929	30,000,000.00	42,000,000.00	120,000.00	168,000.00	0.1200	0.1680
15	Resid. Buildg. 15	11-Nov-11	12-Dec-12	284	40,000,000.00	51,000,000.00	160,000.00	204,000.00	0.1600	0.2040
16	Resid. Buildg. 16	6-Jan-08	16-Oct-18	2811	120,000,000.00	163,000,000.00	480,000.00	652,000.00	0.4800	0.6520
17	Resid. Buildg. 17	21-Apr-10	11-Nov-18	2233	130,000,000.00	137,000,000.00	520,000.00	548,000.00	0.5200	0.5480
18	Resid. Buildg. 18	13-Jun-13	9-Nov-14	367	7,000,000.00	13,500,000.00	28,000.00	54,000.00	0.0280	0.0540
19	Resid. Buildg. 19	2-Dec-10	11-Mar-15	1114	62,500,000.00	87,000,000.00	250,000.00	348,000.00	0.2500	0.3480
20	Resid. Buildg. 20	23-Aug-15	12-Apr-18	688	50,000,000.00	61,000,000.00	200,000.00	244,000.00	0.2000	0.2440
21	Resid. Buildg. 21	28-Feb-10	13-Jul-12	619	15,000,000.00	17,000,000.00	60,000.00	68,000.00	0.0600	0.0680
22	Resid. Buildg. 22	26-Jun-99	18-Dec-00	386	6,000,000.00	7,000,000.00	24,000.00	28,000.00	0.0240	0.0280
23	Resid. Buildg. 23	24-Oct-07	19-Sep-18	2845	120,000,000.00	148,000,000.00	480,000.00	592,000.00	0.4800	0.5920
24	Resid. Buildg. 24	20-Feb-07	15-Dec-07	213	25,000,000.00	23,000,000.00	100,000.00	92,000.00	0.1000	0.0920
25	Resid. Buildg. 25	1-Feb-09	9-Jul-11	634	15,000,000.00	17,000,000.00	60,000.00	68,000.00	0.0600	0.0680
26	Resid. Buildg. 26	11-Aug-07	30-Nov-09	601	7,000,000.00	11,000,000.00	28,000.00	44,000.00	0.0280	0.0440
27	Resid. Buildg. 27	29-Jan-17	2-Oct-18	436	5,000,000.00	7,000,000.00	20,000.00	28,000.00	0.0200	0.0280
28	Resid. Buildg. 28	1-Mar-12	14-Oct-12	162	8,000,000.00	9,000,000.00	32,000.00	36,000.00	0.0320	0.0360
29	Resid. Buildg. 29	2-Dec-98	26-Feb-01	584	33,000,000.00	38,000,000.00	132,000.00	152,000.00	0.1320	0.1520
30	Resid. Buildg. 30	12-Apr-16	1-Jul-18	579	19,000,000.00	23,000,000.00	76,000.00	92,000.00	0.0760	0.0920
31	Resid. Buildg. 31	1-Jan-01	30-Jun-03	650	22,000,000.00	23,000,000.00	88,000.00	92,000.00	0.0880	0.0920
32	Resid. Buildg. 32	1-Aug-06	16-Mar-10	945	33,000,000.00	35,000,000.00	132,000.00	140,000.00	0.1320	0.1400
33	Resid. Buildg. 33	21-Sep-15	31-Oct-17	551	30,000,000.00	39,000,000.00	120,000.00	156,000.00	0.1200	0.1560
34	Resid. Buildg. 34	3-Oct-14	15-Aug-16	487	18,000,000.00	22,000,000.00	72,000.00	88,000.00	0.0720	0.0880
35	Resid. Buildg. 35	26-Jun-11	9-Apr-14	727	27,000,000.00	31,000,000.00	108,000.00	124,000.00	0.1080	0.1240
36	Resid. Buildg. 36	29-May-03	20-Jul-05	559	46,500,000.00	48,000,000.00	186,000.00	192,000.00	0.1860	0.1920
37	Resid. Buildg. 37	19-Oct-16	17-Jul-18	454	57,000,000.00	63,000,000.00	228,000.00	252,000.00	0.2280	0.2520
38	Resid. Buildg. 38	1-Mar-17	30-Nov-17	196	20,000,000.00	27,000,000.00	80,000.00	108,000.00	0.0800	0.1080
39	Resid. Buildg. 39	10-Mar-17	22-Jul-18	356	14,000,000.00	16,200,000.00	56,000.00	64,800.00	0.0560	0.0648
40	Resid. Buildg. 40	27-Nov-08	31-Jan-11	568	15,000,000.00	19,000,000.00	60,000.00	76,000.00	0.0600	0.0760
41	Resid. Buildg. 41	12-Dec-05	10-Nov-17	3108	126,000,000.00	151,000,000.00	504,000.00	604,000.00	0.5040	0.6040

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Table 3: Details of Costs and Durations of Building Projects

S/N	Project title (Buildings only)	Actual duration (days)	Actual Contract sum (Aus$1million)	Predicted Duration (days)	Predicted Contract sum (Aus$1million)
1	Residential Building 1	387	0.0760	458	0.0580
2	Residential Building 2	612	0.0900	509	0.1208
3	Residential Building 3	586	0.0249	229	0.1127
4	Residential Building 4	565	0.1640	741	0.1062
5	Residential Building 5	358	0.0960	530	0.0511
6	Residential Building 6	448	0.1400	671	0.0732
7	Residential Building 7	204	0.0364	290	0.0208
8	Residential Building 8	441	0.1560	718	0.0713
9	Residential Building 9	2707	0.9120	2161	1.3082
10	Residential Building 10	405	0.0600	396	0.0623
11	Residential Building 11	3831	1.1200	2457	2.2826
12	Residential Building 12	554	0.0640	412	0.1030
13	Residential Building 13	526	0.0800	473	0.0946
14	Residential Building 14	929	0.1680	752	0.2358
15	Residential Building 15	284	0.2040	849	0.0352
16	Residential Building 16	2811	0.6520	1753	1.3899
17	Residential Building 17	2233	0.5480	1573	0.9608
18	Residential Building 18	367	0.0540	370	0.0532
19	Residential Building 19	1114	0.3480	1185	0.3154
20	Residential Building 20	688	0.2440	949	0.1456
21	Residential Building 21	619	0.0680	428	0.1228
22	Residential Building 22	386	0.0280	246	0.0578
23	Residential Building 23	2845	0.5920	1650	1.4166
24	Residential Building 24	213	0.0920	517	0.0222
25	Residential Building 25	634	0.0680	428	0.1279
26	Residential Building 26	601	0.0440	326	0.1174
27	Residential Building 27	436	0.0280	246	0.0702
28	Residential Building 28	162	0.0360	288	0.0144
29	Residential Building 29	584	0.1520	707	0.1119
30	Residential Building 30	579	0.0920	517	0.1103
31	Residential Building 31	650	0.0920	517	0.1330
32	Residential Building 32	945	0.1400	671	0.2422
33	Residential Building 33	551	0.1560	718	0.1019
34	Residential Building 34	487	0.0880	502	0.0838
35	Residential Building 35	727	0.1240	622	0.1591
36	Residential Building 36	559	0.1920	817	0.1045
37	Residential Building 37	454	0.2520	969	0.0749
38	Residential Building 38	196	0.1080	571	0.0194
39	Residential Building 39	356	0.0648	415	0.0508
40	Residential Building 40	568	0.0760	458	0.1071
41	Residential Building 41	3108	0.6040	1671	1.6321

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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	871.028	750.259	Mean	0.20327	0.30442
Variance	811587	281769	Variance	0.06119	0.2784
Observations	41	41	Observations	41	41
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
Df	40		Df	40	
t Stat	1.68959		t Stat	-2.12966	
P(T<=t) one-tail	0.04944		P(T<=t) one-tail	0.01970	
t Critical one-tail	1.68385		t Critical one-tail	1.68385	
P(T<=t) two-tail	0.09889		P(T<=t) two-tail	0.03940	
t Critical two-tail	2.02108		t Critical two-tail	2.02108	
Correlation	R^2	R^2 (adj.)	Correlation	R^2	R^2 (adj.)
	0.6137	0.5824		0.6137	0.5824

4. CONCLUSION

The study showed that inadequate inflow of funds is the major cause of both cost overrun and delay in the completion time. The uniqueness of the Port Harcourt situation of private residential buildings has called for the formulation of a model based on the Bromilow's Time-Cost model. The model showed that it will take 2289.2 working days to complete a private residential building project for every Aus$1 million. This is way greater than the results found by most other researchers. The BTC model was however found to be adequate and fit, as it passed the two-tailed student t-test and yielded an R^2 value of 61.37%. Contrary to Waziri and Yusuf (2014), and Ogunsemi and Jagboro (2006), the model can be used in the Nigerian construction industry, especially in Port Harcourt for private residential buildings. However, further improvement needs to be done by also considering public residential, private office, and public office buildings.

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