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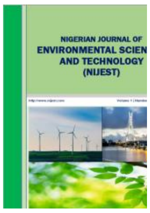

Measuring and Modelling Overruns in Highway Project Costs in Nigeria

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ABSTRACT

Overruns in highway project costs are pervasive globally. Recent attempts at predicting highway cost overruns predominantly rely on the use of after-the-fact machine learning predictive models that mainly address developed country contexts. The present study estimated the extent of cost overrun in Nigerian highway projects, and developed a regression model for predicting cost overruns in such projects based on the winning tender. Secondary data for the study was obtained from the website of the Nigerian Federal Ministry of Works and Housing, and covered the period 2002 to 2015. The overall average cost overrun for Nigerian highway projects was determined to be 17.37%. Additionally, a logarithmic model for estimating cost overrun at the pre-award stage of highway projects was obtained as $Log_{10}(Costoverrun) = 0.844 + 0.914Log_{10}(initialcost)$. *In the context of this study, it is better to estimate overruns in highway projects after the successful bidder has been identified, and to add the estimated cost overrun as a contingency sum to the contractor's bid at that stage. Measures for mitigating cost overrun in highway projects in Nigeria should be intensified.*

Keywords: Cost Overrun, Highway, Modelling, Regression

1.0. Introduction

Globally, overruns in the cost of highway projects have understandably generated heated arguments in the literature particularly due to the cost of such projects and their implications for national economies (Love, et al., 2016; Flyvbjerg et al., 2019; Love et al., 2022). In developing countries, highways are critical for linking agrarian communities with cities where farm produce are needed. Road transport also accounts for up to 90% of movement of persons and goods in countries like Nigeria (Iweze, 2023; Ogbu & Adindu, 2020). According to National Bureau of Statistics (2017), road transport alone contributes above 90% of the GDP of the Nigerian transport sector. It has been estimated that both state and federal governments in Nigeria dedicate 20% of their annual budgets to road projects (Ighodaro, 2009). Of Nigeria's 195000Km of road network, only about one-third are paved (Izuwah, 2017). Irrespective of this, road infrastructure in Nigeria is far from meeting the needs of the citizenry. Substantial portions of the claimed paved roads have failed leading to traffic congestion and accidents. In developing countries with lower GDPs, highway cost overruns can, in addition to fore-running project abandonment, limit the ability of governments to build more highways (Mahmud et al., 2022). An Iranian study by Noorzai (2020) identified the design-build procurement system as the optimal project delivery method for highway projects. However, most public highway projects in Nigeria are procured using the design-bid-build method which might contribute to the cost overruns experienced in such projects.

Although Nigeria has the largest economy in Africa (Statista, 2022a), its other indices of development such as income per capita ($2140) and human development index (HDI 2021=0.535) (United Nations Development Programme, 2022), are low indicating competing pressures from non-infrastructural needs for financial attention. Foresee-ably, Nigeria's investments in highway infrastructure will continue to rise, hence there is need to make the cost of highway projects as predictable and controllable as possible. Models for predicting the final cost and duration of road projects will benefit public ministries and agencies during budgeting, and help highway consultants to fairly determine worst case scenarios of cost overruns for highway projects at the pre-award stage.

Recent studies on the estimation of highway project costs focus more on causal relationships, and compare the cost overrun predictive abilities of different machine learning algorithms (Awuku et al., 2022; Abed et al., 2022; Cao, 2019; Tijanić et al., 2019; Jaafari et al., 2021). However, evidence from these studies show no consensus on the best method for modelling highway cost overruns. Secondly, it has been argued that because machine learning generally tends to encode the infrastructure and culture of developed countries, they are less effectively deployed in developing countries (De-Arteaga et al., 2018). Due to the digital divide (Saka et al., 2022; Windapo, 2021), machine learning models will find limited adoption in developing country construction settings at the moment. Rather, professionals will prefer hand-tool mathematical models that can be applied using easily available and recognizable parameters. Ideally, a model should be simple enough for manipulation and understanding by those who use it, representative enough in the total range of the implications it may have, and complex enough to accurately represent the system. Based on qualitatively obtained data, Mahmud (2021) developed a system dynamics models of cost overrun factors in highway projects in Nigeria aimed at aiding highway project stakeholders in understanding interrelations between cost overrun factors. The model's application in computing numerical values is limited given its use of qualitative inputs. At the pre-contract stage, both bidders and consultants will be benefited by having good ideas of the proneness of the project to cost overrun. The information can aid consultants in making contingency allowances for projects, and help contractors in appropriately allocating costs. Researchers have identified numerous causes of cost overrun, and built predictive models based on these. Mahmud et al. (2021) examined the drivers of cost overrun in highway projects in Nigeria, and found the key factors to be delay in work progress, political instability, adverse weather conditions among others. Other factors such as price fluctuation (Omoregie & Radford, 2006); rework (Susanti & Nurdiana, 2020), and shortage of materials (Kamaruddeen et al., 2020) have also been identified in literature. Further, existing studies tend to use after-the-fact factors (Herrera, et al., 2020; El-Kholy, 2021) that are not normally available at the pre-construction stage of highway procurement.

In the present study, cost overrun was modeled based on association rather than causation. A non-causal relationship is one in which variables are related to each other, without either variable directly affecting the value of the other (Segura-Egea, et al., 2019). A model forecasting cost overrun from the initial cost of highway projects (as in this study) is non-causative since initial costs do not necessarily affect the value of cost overruns in a project, though they are associated with each other. Initial cost, for this study, refers to the contract sum at which a highway project was first awarded. Cost overruns primarily occur because agreed contract sums are exceeded in the cause of a project. Contract sums arise from the winning tender. Thus, they are based on contractors' rather than consultants' estimates. A cost overrun model based on contractors' price of the project is hardly known to exist in literature.

Nigerian studies on highway project cost overrun rely overly on opinion data (Anigbogu, et al., 2019; Mahmud et al., 2021), and are hardly directed at development of models for predicting overruns in future highway costs. Amadi and Higham (2016), which is an exception, developed a model for predicting highway cost overrun. The study focused on a section of the country (Niger Delta region of Nigeria) and used geotechnical variables like plasticity index, plastic limit and liquid limit of soil. It may be difficult to use Amadi and Higham's (2016) predictive models in practice since a road project can have different geotechnical profiles at different points along the road alignment. The objectives of the present study are to determine the extent of cost overrun in highway projects, and develop a model for estimating cost overruns at the pre-award stage of highway construction procurements in Nigeria.

2.0 Methodology

The goal of this study was to develop a desktop-model for estimating the approximate cost overrun of highway projects in Nigeria at the pre-contract stage. A quantitative approach was adopted using secondary data on highway projects obtained from Federal Ministry of Works and Housing (2017). The list contained highway projects in all six zones of the country, on-going or completed during the period 2002 and 2015. This secondary data was chosen given Le et al.'s (2019) assertion that historical costs are important to the forecast of future construction costs. The sample frame contained a total of 229 projects. The data also revealed the projects' length (km), original/initial contract sum, revised contract sum, commencement date, completion date, and extended completion date. The model was developed using multiple regression analysis (MRA). MRA uses the F-test to analyse the relationship between a dependent variable and two or more independent variables (Abhilash et al., 2021). The relationships can then be used to predict an outcome (Kahane, 2001). A typical linear regression model is shown in equation 1 (Seiber & Lee, 2003).

$$Y_i = \alpha + \beta x_i + \varepsilon_i \quad (1)$$

Where $\boldsymbol{Y_1}$ is the dependent variable (the predicted variable), $\boldsymbol{\alpha}$ is the intercept (when $\boldsymbol{X_i}$ is equal to 0), $\boldsymbol{\beta}$ is the slope of the line and $\boldsymbol{X_i}$ is the independent variable (the predictor variable), and ε_i is the error term.

The analysis in this study was carried out following the procedure enumerated by Elmousalami (2020). Regression analysis requires the variance of the random error to be constant across the observations, and the residuals of the regression to be normally distributed (Đalić & Terzić, 2021). According to Yang et al. (2019), these assumptions ensure that valid inferences are drawn from regression model coefficients. For this study, the normality assumption was tested using the normal P-P plot of the regression residuals (Alita, et al., 2021), while the homoscedasticity was tested by plotting the regression standardized residuals against the standardized predicted values of the dependent variable along the X-axis. Further, the homoscedasticity was confirmed using the Glejser's Test (Đalić & Terzić, 2021), in which the absolute values of the unstandardized residuals were regressed against the independent variable in the forms shown in equations 2, 3 and 4. Obtaining p-values >0.05 will confirm homoscedasticity.

$$|e_i| = \alpha_o + \beta_1 X_i + \upsilon_i \quad (2)$$

$$|e_i| = \alpha_o + \beta_1 \sqrt{X_i} + \upsilon_i \quad (3)$$

$$|e_i| = \alpha_o + \frac{\beta_1}{X_i} + \upsilon_i \quad (4)$$

Where $|e_i|$ is the absolute value of the residual, and α_o, β_1 and υ_i represent the intercept, slope and error of the models respectively.

The variables of the model developed in this study were defined in Table 1. Initial/original contract sum is the value of the winning bid for the project. It is the contractor's offer for executing the works which was accepted by the client. Most civil engineering projects like roads are awarded using re-measurement forms of contract, entailing that original contract sums will vary from the final amounts to be paid to contractors due to several risk factors (Ogbu & Adindu, 2019). Simple models for predicting overruns in road project costs (and, therefore, the final account sum) at the pre-award stage are scarce.

Table 1: Main Variables of the Study

S/N	Variable	Variable Type	Description
1	Initial Cost	Independent	Initial cost is the initial contract sum of the successful bidder
2	Cost Overrun	Dependent	Cost overrun is the value by which the initial contract sum was exceeded in the course of the project execution

2.1 Data Treatment

Out of the 229 projects listed in the sample frame, 32 were eliminated for not having their lengths and/or duration stated. Another 24 cases were eliminated because they contained the costs of bridges which distorted the data giving rise to outliers. This reduced the number of cases to 173. Out of this number, 86 cases were randomly chosen for the development of the model, while the remaining 87 were kept for validation of the model. In order to determine the best variable for predicting cost overrun based on the data set, a number of trial regression analyses were executed in the Statistical Package for Social Sciences (SPSS) version 27. According to de Rooij and Weeda (2020), this approach helps to identify the model that yields the best predictions based on the data set. The first attempt at simple regression between *length of road* and *costoverrun* yielded p-value of 0.25 and adjusted R^2 value of 0.023. A second regression was done which related the *initial cost* to the *costoverrun.* A significant relationship was obtained with a p-value of 0.000 and an adjusted R^2 value of 0.572 proving that a substantial linear relationship exists between the initial cost of highway projects and their cost overrun. However, in order to improve the normality of the data (Benoit, 2011), the *initial cost* and *cost overrun* data were logarithmically transformed to generate that data used in the analysis. Data transformation helps to improve the normality of data, and therefore, the resulting linear regression models (Elmousalami, 2020).

3.0 Results and Discussion

3.1 Descriptive Statistics of the Data

Descriptive statistics of the secondary data obtained for the study are shown in Tables 2 and 3. The mean cost overrun of the projects is ₦1,967,264,762.00, while the mean initial cost is ₦8,825,530,009.00. Cost overruns were reported in only 32 of the 173 projects (Table 3). This might be because some of the projects were yet uncompleted at the time the data was captured or because there were cost limits which the projects were not allowed to exceed.

Table 2: Summary Statistics of Initial Cost and Cost Overrun

	Cost Overrun	Initial Cost
Number of Projects	173	173
Minimum	0	173,205,648
Maximum	29,474,005,427	96,304,444,056
Mean	1,967,264,762	8,825,530,009
Std. Error	443,572,481.8	1,109,842,185
Std. Deviation	5,834,285,094	14,597,694,815
Variance	3.40389E+19	2.13093E+20

Table 3: Distribution of the Projects by Cost Overrun

	Number of projects	Percentage of Projects (%)
Underrun	0	-
None	141	82.00
Overrun	32	18.00
Total	173	100.00

Table 4 shows the different sizes of cost overrun in the road projects with roads of ≤33Km having the lowest mean cost overrun (₦252,904,503.64), while roads of ≥66Km have the highest mean cost overrun(₦4,781,444,363.81). It is evident that cost overrun gets worse as the size of road projects increase. Based on the data, the mean cost overrun in Nigerian road projects is 17.37% (lower limit=0.00%, upper limit =201.82%). It is defined as actual cost minus estimated cost in percent of estimated cost (Flyvbjerg et al., 2004).

Table 4: Road Sizes and Cost Overrun

Size of Road (Length in Km)	Mean cost overrun (Naira)	N	Std. Deviation	Mean % Overrun
≤33Km	252,904,503.64	90	1,179,765,286.37	7.33%
>33≤66Km	3,195,754,689.72	50	7,250,919,535.54	15.67%
≥66Km	4,781,444,363.81	33	8,932,522,083.08	28.32%
Total	1,967,264,761.96	173	5,834,285,094.36	17.37%

3.1 Inferential Tests – ANOVA Test

ANOVA test was carried out to determine whether the differences in cost overrun for the 3 groups of road sizes is significant. The result showed that the hypothesis of no difference should be rejected (F=9.729, p=0.000), with the conclusion that a significant difference exists between cost overruns in difference sizes of road projects. Scheffe's multiple comparison test was carried out to identify the group of roads responsible for the significant difference in cost overrun. As shown in Table 5, roads of ≤33Km have significantly lower cost overrun than the longer roads.

Table 5: Scheffe Multiple Comparison Test

Size of Road		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
≤33Km	>33≤66	-2942850186.08020*	980510474.10411	.012	-5364194395.1489	-521505977.0115
	≥66	-4528539860.17633*	1131276608.82737	.000	-7322196978.5685	-1734882741.7842
>33≤66	≤33Km	2942850186.08020*	980510474.10411	.012	521505977.0115	5364194395.1489
	≥66	-1585689674.09613	1246784947.62760	.447	-4664591524.3293	1493212176.1370
≥66	≤33Km	4528539860.17633*	1131276608.82737	.000	1734882741.7842	7322196978.5685
	>33≤66	1585689674.09613	1246784947.62760	.447	-1493212176.1370	4664591524.3293

*. The mean difference is significant at the 0.05 level.

3.2 Regression Analysis

Tests of homoscedasticity and normality (using the normal p-p plot) were carried out on the data.

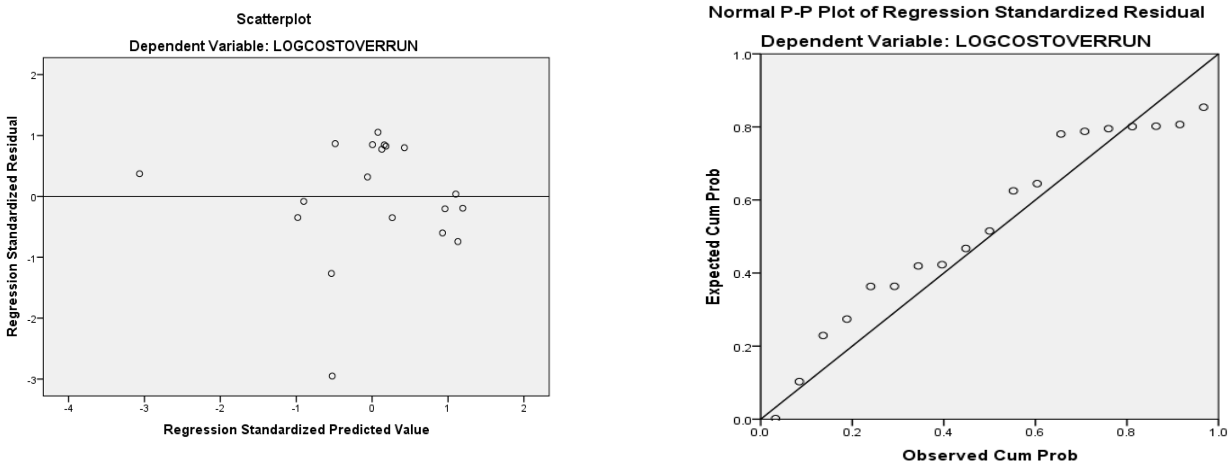

Figure 1: Homoscedasticity and Normality Plots

The results are shown in Figure 1. The scatter plot shows that there is no serious heteroscedasticity problem in the data. However, this was further confirmed using the Glejser's Test, based on equations 2, 3 and 4, and were all found to have p-values >0.05, which confirm the absence of heteroscedasticity.

Results of the linear regression between loginitialcost (independent variable) and logcostoverrun (dependent variable) are shown in Table 6. A significant positive relationship was found to exist between the two variables (p-value=0.000), with adjusted R^2 value of 70.6%. Table 3 shows that the relationship between Logcostoverrun and Loginitialcost can be expressed using equation 5 below.

$$Log_{10}(Costoverrun) = 0.844 + 0.914Log_{10}(initialcost) \quad (5)$$

Table 6: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.900a	0.810	0.794	0.26347	0.810	51.057	1	12	<0.001	1.484

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.844	1.266		.667	.517
	LOGINITIALCOST	.914	.128	.900	7.145	<0.001

a. Dependent Variable: LogCostoverrun

3.3 Model Validation

To test the validity of the model, predicted and observed cost overruns for the remaining 87 cases were compared using independent sample t-test. The hypothesis that there is no significant difference between the observed and predicted cost overruns was tested. As shown in Table 7, it was observed that a significant difference does not exist between the predicted and observed cost overruns (t=-.246, p=0.808). Consequently, the model was accepted as valid.

Table 7: Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
VAR00001	Equal variances assumed	6.727	0.011	-0.305	103	0.761	-0.04503	0.14742	-0.33739	0.24734
	Equal variances not assumed			-0.246	20.756	0.808	-0.04503	0.18318	-0.42624	0.33619

Odeck (2004) found that small projects accounted for most cost overruns, on the contrary, the results of this study show that the longer (larger) roads account for the most cost overruns. This is because mean cost overrun increased from 7.33% for road projects of length ≤33Km to 15.67% for roads of >33≤66Km and to 28.32% for road projects of ≥66Km. Additionally, This study's result on overall percentage overrun in the costs of highway projects (17.37%) is similar to Flyvbjerg et al. (2002) which found the overrun to be 20.4%. It however differs from the finding of Odeck (2004) which gave the mean overall cost overrun as 7.9%. Possibly, certain best practices in highway project procurement are applicable in Norway but absent in other countries. The result suggests that the magnitude of overruns in highway project costs vary between countries.

Plebankiewicz (2018) developed a model for predicting cost overruns in building projects based on the costs of building elements. In this study, however, the objective was to develop a simple model for predicting cost overruns in road projects. Odeck (2004) found a significant relationship between estimated and actual costs of road projects in Norway. Other independent variables of the model included: delay in completion, completion time, region, and workforce type. Although this study concurs with Odeck (2004) regarding the significance of the initial estimate in predicting the actual cost of a road project (i.e., cost estimate plus cost overrun or minus underrun), it differs in using the initial contract sum as the sole predictor variable. The model derived by this study thus offers a simpler tool for cost overrun prediction before the contractor is mobilized to site.

4.0 Conclusions

It is generally known that cost overruns are widespread in highway projects. In Nigeria, there is hardly any recent estimation of the extent of cost overrun in highway projects. Also, Extant studies hardly provide any tool for easy estimation of the risk of cost overrun in highway projects in Nigeria. Based on the results of this study, it is concluded that cost overruns tend to become worse as the size of road projects increase. Likewise, the mean cost overrun in road projects in Nigeria is nearly one-fifth of the initial cost estimate (17.37%). Using regression analysis, this study also established the model for predicting cost overruns in highway projects as shown in equation 5.

The implications of this study for policymakers and practitioners are that highway projects should be awarded in sizes that are small enough for contractors to manage effectively. It is apparent that awarding longer roads to a single contractor leads to risk events that occasion cost growth. Secondly, at the budgetary level, a contingency sum of up to 17.37% should be allowed for road projects to accommodate unforeseen events that will impact the project cost negatively. Better still, the model in equation 5 should be used to establish the cost overrun for individual projects at the pre-award stage. Thus, rather than arbitrarily include a contingency sum to a highway project at the design stage, this can be added after a contractor has been chosen, and estimate of the contingency sum made using model obtained in this study and based on the winning tender.

Also, the national average cost overrun for Nigeria needs to be reduced by adopting best practices across the highway procurement value chain.

For the academia, the results of this study suggest that useful models can be obtained by identifying associative relationships, rather than solely causative relationships. Construction management scholars should widen the search for predictive models to non-causative associations with a view to

possibly validating existing causative models. Further studies in this area based on more recent and larger data should be undertaken to further enrich the understanding of cost overrun in Nigerian highway projects.
Some of the projects covered by the study were not completed at the time of the study. Consequently, further cost growths in such projects were not captured by the study. Secondly, other specifics of the highway projects such as road widths, type of pavement, presence/absence of side drains, which might affect the reliability of the model, were unavailable for consideration at the time of the study. Future research can leverage the availability of additional information to improve on the predictive power of the model developed in this study.

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