

Elemental analysis of road construction cost overruns

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Abstract:

Road is an important channel of transporting goods and services, and the most used mode in Nigeria. Its development, however, is fraught with a lot of challenges including cost overruns. Despite numerous studies on cost overruns, there is a paucity of literature on the elemental cost overruns analysis on road construction projects. Analyses of historic data using ANOVA and questionnaire survey data using Friedman's Analysis revealed a significant difference in the extent of cost overruns on the road construction stages (pavement layers). However, in terms of historical data, the base course was the most vulnerable to cost overruns, whereas in the questionnaire survey data analysis, clearance and earthwork course was the most vulnerable to cost overruns. As no two roads are exactly the same, it is concluded that the susceptibility of road construction project stages (courses) to cost overruns varies for different roads. As a result, the study suggests that effective construction management, regular monitoring, and communication be implemented to reduce cost overruns in road projects.

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1. Introduction

Although roads contribute significantly to economic development, their construction is an expensive public procurement activity. Several road construction projects in Nigeria have been developed at far higher costs than anticipated. Instances include the construction of the Kano Western By-pass, which was estimated to cost N15.045 billion but was revised to N22.774 billion, representing a cost overrun of 51.37% [1]. The 196-kilometer Abuja-Abaji-Lokoja Road, which was estimated to cost N42 billion but was revised to N116 billion, representing a cost overrun of 176.2% [2]. Cost overruns are regarded as the main technical risk in road construction and pose the highest level of financial risk to the owner [3]. The most common causes of these overruns identified by various studies include man related factors [4] inflation, inaccurate estimates, design changes [3], site conditions, change orders, rework [5].

Despite numerous studies that have been conducted to determine the causes of cost overruns' persistence, there is a dearth of literature on cost overruns for each road component. As a result, the purpose of this study is to conduct an elemental analysis of road construction project cost overruns in order to reduce them. A hypothesis is proposed thus: H_0 : There is no significant difference on the extent of cost overruns on road construction stages.

1.1 Stages in road pavement construction

Roads are made of several different layers of carefully selected materials designated to distribute load from the surface of the pavement to the under-laying layers. The flexible pavement is shown in Figure 1, from the top to the

bottom consists of the surface layer, base course and the sub base.

Prior to the commencement of any road construction project, site investigations must be carried out to establish the geological profile along the road alignment. The next operation to be undertaken in the construction of road is the preparation of the right of way and any designated easement. The right of way is then excavated to the formation level of the road. The excavated material, where the formation level (the subgrade layer) is below the natural ground is then carted to adjacent areas to be used as fill where the formation level is above the natural ground. An ideal design uses all the excavated materials from cuttings to almost form the embankment where filling is required; unless the quality of material is poor; this also minimises the moved distance. The earthwork cost is calculated by estimating the number of cubic meters of soil and rock moved in the process of constructing the road.

Earthwork cost is a function of hauled amount multiplied by the hauled distance. The cost of excavating the soil and rock materials is usually one of the largest single costs of road construction projects. Abeli, [6] stated that the process of preparing the subgrade constitute a major cost in road construction works. Subgrade work forms about 50% of the total construction cost of a road project [7]. However, [8] showed that road projects' earthworks in Palestine constituted only 7% of road construction cost. Mahamid [8] also found that earthworks were overestimated and the average cost deviation was -15.7%.

The sub-base, which is usually a layer of laterite and 150 mm (FCTA specification) thick is laid immediately to

avoid damage from rain or sun baking, which could cause surface crack of the subgrade layer. It is then compacted by multiple passes of the selected equipment until full compaction is achieved. The sub-base is mainly the load bearing layer and serves to transmit traffic loads to the subgrade while providing drainage protection. It works by

distributing wheel load over a larger area. The cost of sub base for a road pavement is largely dependent on its thickness, which is dependent on the CBR of the subgrade and the cumulative number of standard axles to be carried by the pavement during its design life.

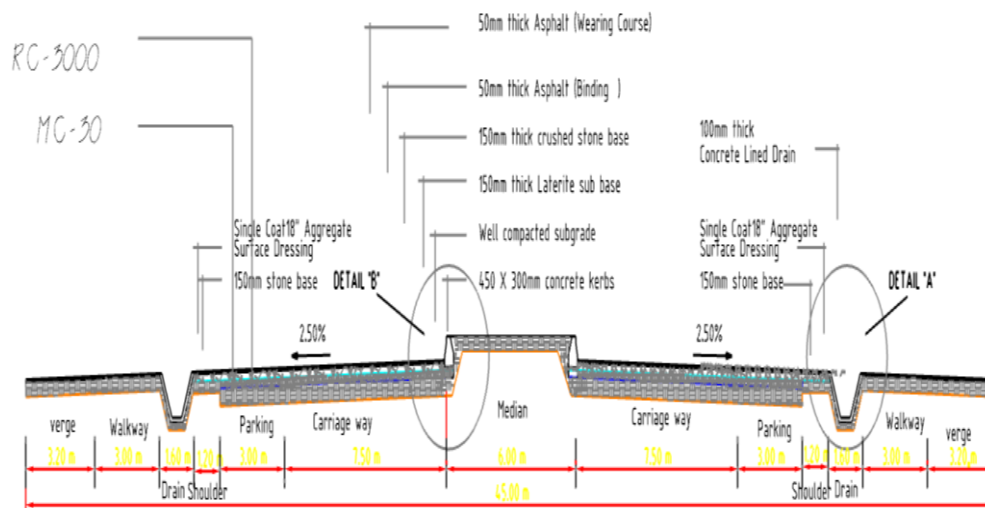


Figure 1 Section of a typical STDA flexible road pavement (2014 STDA Construction Working Drawings)

The base course, which is the pavement layer immediately beneath the surfacing is an important structural layer of a road pavement that is responsible for transferring and distributing traffic loads to the subgrade [9]. It is composed of granular material that is laid and compacted in layers not exceeding 150 mm and compacted to refusal by multiple passes with a heavy smooth vibrating roller. A prime coat is applied to provide a bond between the base and the asphalt courses, and provides an additional seal against the ingress of water. Mahamid [8] posited that the base course constitutes 24% of the road construction cost. This layer of road pavement according to [8] was more prone to cost underestimation than cost overestimation and the average cost deviation was 12.86%.

The surface course is composed of two layers of various selected aggregates and bituminous cement comprising of the binder and wearing courses. The 50 mm binder is a bituminous concrete layer below the wearing course and above the stone base. It supports the wearing course and also protects the stone base. The 50mm wearing course is the uppermost layer of the road pavement structure, which is in direct contact with the traffic loads and normally contains the highest quality material [10]. It provides characteristics such as friction, smoothness, noise control, drainage, etc. The wearing course is made up of various selected aggregates bound together with asphalt cement or other bituminous binders [2].

The surface (asphalt) course is made up of the highest load bearing capacity materials and is also the most expensive layer of the flexible pavement. According to Mahamid [8], asphalt course represents 48% of the total road pavement construction cost. Mahamid [8] also found that cost underestimation was more predominant in asphalt work than

other road layers. Mahamid [8] further reported that 88% of asphalt course cost was underestimated and the average cost overruns was 22.25%.

2. Methodology

A thorough review of relevant literature in related works yielded the necessary information for this study. The information gathered served as the foundation for data collection and analysis. Data for the study were obtained from various consultancy outfits, contractors, and client organizations that have worked on the Federal Capital Territory Administration, Abuja Road construction projects via questionnaire survey and examination of road construction project documents.

The questionnaire survey was administered to 267 clients, consultants, and contractors involved in road construction projects in the Federal Capital Territory Administration, Abuja. This was part of a PhD thesis, so the sample size for the questionnaire survey was based on the requirements for Partial Least Square Structural Equation Modelling used for the analysis. The respondents were asked to rank the susceptibility of the 4 stages of road construction to cost overruns.

This study employed the principle of elemental cost analysis estimating technique, which uses the elemental cost of previous similar projects as a basis for estimating. Elemental cost analysis is usually carried out to show the relationship between several sections or part of a project. The cost analysis is prepared by examining the cost of projects, which had been constructed. The cost of the project was broken down into elements and sub elements so that it was possible to make adjustments for variations in

design in the new project as compared to historical projects from which the data was obtained [9].

Project activities are organized into groups to reflect different stages of the construction process. This study's groups included clearance and earthwork to subgrade, sub-base, base course, and asphalt coarse. This analysis was conducted in two parts: an examination of historic cost data from project documents and an examination of the ranking of responses on the severity of cost overruns on road construction stages. For the questionnaire survey data, the respondents ranked the cost overruns encountered during the various stages of road construction. These tests were carried out to test the hypothesis regarding the extent of cost overruns on different stages of road construction.

ANOVA, a parametric test, was used to compare the variability in cost overruns of the different road stages for the historic construction data. The non-parametric alternative to one-way ANOVA with repeated measures, Friedman's two-way analysis of variance by ranks, was used to test whether there is agreement among the ranks of elemental cost overruns for the analysis of the questionnaire survey.

To know where the differences lie, post hoc tests (Wilcoxon signed-rank tests) were conducted between:

- Clearance & Earthwork and Sub base
- Clearance & earthwork and base courses
- Subbase and base courses
- Subbase and asphalt courses
- Base course and Asphalt, and
- Asphalt and Clearance & Earthwork

A Bonferroni adjustment was done on the results of the Wilcoxon tests to eradicate the possibility of declaring a result significant when it is not (Type I error). This was done by dividing the significance level (0.05) by the number of tests conducted, which in this case is 6.

3. Results and discussion

The age of respondents is an important feature of the collected data. It demonstrates the respondents' maturity level and, in most cases, their experience. Table 1, shows that all respondents have at least 5 years of experience with road construction projects. This indicates that the survey was conducted by well-experienced personnel with knowledge of road construction. Their level of education also suggests that they are competent and capable of making sound decisions. As a result, they can provide the researchers with the necessary information for the study, and the responses received can be trusted.

3.1 Data screening and normality test

A normality test on the historical data reveals that the skewness and kurtosis values for all road phases (pavement

layers) were between -2 and 2. A further test was performed to see if the observed skewness and kurtosis were statistically different from the expected values. Dividing the obtained values by their standard errors yielded z values of 1.96, indicating that the data distribution was well within the 1.96 limits and not statistically different from the normal distribution. The results of the Kolmogorov-Smirnov and Shapiro-Wilk tests show that both p-values are greater than 0.05, indicating that the sample data set is not significantly different from normal.

Table 1 Respondents' Demography

Category		Frequency	Percentage
Age (years)	< 30	3	1.12
	31 – 40	86	32.31
	41 – 50	143	38.95
	51 -60	74	21.72
Organisation	Client	106	39.70
	Contractor	99	37.08
	Consultant	62	23.22
Education	OND	19	7.12
	HND/BSc	130	48.69
	MSc	97	36.33
	Ph.D.	21	7.87
Experience (years)	6 – 10	77	28.84
	11 -15	45	16.85
	16 – 20	85	31.84
	≥ 20	60	22.47
Number of road projects worked on	≤5	58	21.72
	6 – 10	82	30.71
	> 10	127	47.57

3.2 Extent of cost overruns on road construction stages

The hypothesis that there is no significant difference of cost overruns extent on road construction stages was to establish which of the road construction stage was most prone to cost overruns. The susceptibility of the road construction stages to cost overruns was tested using both road projects historic data and data obtained from the questionnaire survey. Analysis of variance was used for the road cost overruns historic data while Friedman's test was used to test the questionnaire survey data.

There was statistically significant difference between groups as determined by ANOVA $F(2.6355) = 6.2139$, $p = 0.0004$: $p < 0.005$ as shown in Table 2 (a and b). Therefore, the null hypothesis; there was no significant difference between cost overruns in road construction stages was rejected and the alternative hypothesis was accepted.

Result of a post hoc test conducted between subjects to know which of the road construction projects' stages differ significantly is shown in Table 3.

Table 2a: Analysis of variance (One-Way) for road stages cost overruns

Overruns on Clearance and Earthwork	Sample size	Sum	Mean	Variance
Overruns on Sub Base	74	5,384.16	72.759	2,107.994
Overruns on Base Course	74	4,773.09	64.501	1,355.554
Overruns on Asphalt Courses	74	5,901.13	79.745	700.613
	74	4,436.59	59.954	539.308

Table 2b: Analysis of variance

Source of Variation	SS	Df	MS	F	p-level	F crit
Between Groups	19810.919	3	6603.639	6.214	0.0004	2.636
Within Groups	310314.564	292	1062.721			
Total	330125.482	295				

Table 3 Multiple Comparison Tukey HSD result (multiple comparisons) cost overruns as dependable variable

(I) Road Stages	(J) Road Stages	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Clearance and Earthwork	Sub base	5.825	4.65381	0.594	-6.1999	17.8499
	Base	-9.86581	4.65381	0.149	-21.8907	2.1591
	Asphalt	8.75486	4.65381	0.238	-3.27	20.7798
Sub base	Clearance and Earthwork	-5.825	4.65381	0.594	-17.8499	6.1999
	Base	-15.69081*	4.65381	0.005	-27.7157	-3.6659
	Asphalt	2.92986	4.65381	0.922	-9.095	14.9548
Base	Clearance and Earthwork	9.86581	4.65381	0.149	-2.1591	21.8907
	Sub base	15.69081*	4.65381	0.005	3.6659	27.7157
	Asphalt	18.62068*	4.65381	0.000	6.5958	30.6456
Asphalt	Clearance and Earthwork	-8.75486	4.65381	0.238	-20.7798	3.27
	Sub base	-2.92986	4.65381	0.922	-14.9548	9.095

The Tukey post hoc test revealed significant difference between the subbase and base (0.005) courses and between the base course and asphalt layers (0.000). However, there were no significant differences between clearance and earthwork (C&E) and other stages, and between sub-base and asphalt.

Table 4: Post Hoc Test (Tukey HSD^a) – Homogenous Subset (Cost overruns)

Road Stages	N	Subset for alpha = 0.05	
		1	2
Asphalt	74	59.9539	
Sub base	74	62.8838	
Clearance and Earthwork	74	68.7088	68.7088
Base	74		78.5746
Sig.		0.238	0.149

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 74.000.

The line graph in Figure 2 displays the mean plot of road pavement construction stages cost overruns also clearly depicts the differences, showing that the cost overruns on the base course are more critical.

The result displayed in Table 5 is that of the Friedman's Test on the responses on the stages of road construction projects that experience the highest rate of cost overruns. The result shows that there is statistically significant difference among the cost overruns in the four stages of road construction analysed. The Bonferroni adjustment on Wilcoxon result was $0.05/6 = 0.008$ which means that the result is statistically significant if p is not greater than 0.008.

The result displayed on Table 6 shows the output of the Wilcoxon signed-rank-test on each of the combinations.

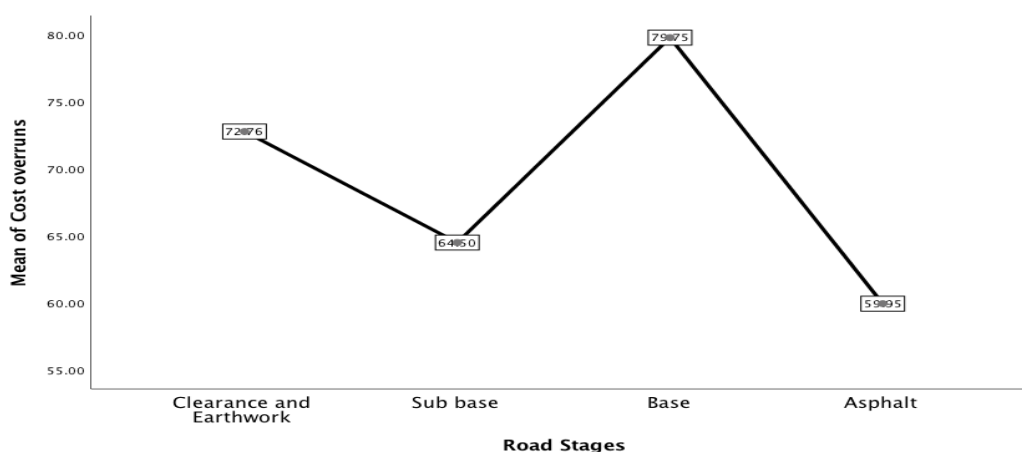


Figure 1: Means plot for road stages cost overruns

Comparing the results with the Bonferroni adjusted significance of 0.008, it is clear that there was statistically significant difference in cost overruns depending on the stages of road construction ($\chi^2 = 28.435$, $p = 0.008$). There were significant differences between the clearance &

earthwork stage and the other three (3) stages, however, there were no significant differences between subbase and base, sub base and asphalt, and between base and asphalt. The findings from both the questionnaire survey and the contract documents on the most vulnerable road

construction stage to cost overruns revealed significant differences in the magnitude of cost overruns among the stages. The findings from construction documents revealed that the base course of road construction projects had the highest cost overruns when compared to the subbase and asphalt courses. This agrees with [5] study that showed the base course as the layer with highest cost overruns. It was also discovered that, while the clearance and earthwork to subgrade course did not differ significantly from the subbase and asphalt courses, it was also prone to cost overruns.

Table 5: Friedman's Test Result

Ranks	Mean Rank
Overruns on Clearance and Earthwork	2.98
Overruns on Sub Base	2.21
Overruns on Base	2.35
Overruns on Asphalt Courses	2.46
Test Statistics	
N	267
Chi-Square	64.450
Df	3
Asymp. Sig.	.000

Table 6: Wilcoxon signed-rank -test

	Overrun on Sub Base - Clearance and Earthwork	Overrun on Base - Clearance and Earthwork	Overrun on Asphalt Courses - Clearance and Earthwork	Overrun on Base - Sub Base	Overrun on Asphalt Courses - Sub Base	Overrun on Asphalt Courses - Base
Z	-7.761 ^b	-5.562 ^b	-4.190 ^b	-2.163 ^b	-3.077 ^b	-1.731 ^b
Asymp. Sig. (2-tailed)	.000	.000	.000	.031	.002	.084

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

Results of the questionnaire survey however showed that the clearance and earthwork construction stage was the most susceptible to cost overruns. This finding counteracts [5], which revealed that earthworks were overestimated and the average cost deviation was -15.7%. The disparities in cost deviations between the two results could be attributed to the fact that the historic data was for FCTA projects, whereas the survey data analysis was for respondents' overall experience in Nigerian road construction.

4. Conclusion

The study used elemental analysis to investigate the susceptibility of FCTA road projects stages (layers of the pavement) to cost overruns. The findings from both questionnaire survey and contract documents on the most vulnerable road construction stage to cost overruns revealed significant differences in the magnitude of cost overruns among the stages. However, according to the contract documents, the base course was the most vulnerable to cost overruns, while the clearance & earthwork stage was the most susceptible, according to the questionnaire survey findings. Although both clearance & earthwork course and base course are crucial stages of road construction, the base could be more susceptible to cost overruns due to complexities and precision required in its construction.

It is therefore concluded that cost overruns can occur at any stage of road construction and the severity of the overruns on the road stages varies for different roads as all road projects are unique. Hence, effective construction management from project inception to completion, regular monitoring, and communication can go a long way in minimising cost overruns in road projects.

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