Metropolitan Journal of Engineering and Technology
ISSN: 3006-4368
Vol. 5 Issue 10, October- 2026, Pages: 260-271

The Effect of Construction Materials Quality on the Performance of Road Infrastructure in Uganda: A Case Study of Selected Road Projects

Tumwine George[1], Mamanero Benjamin[2]
1, 2 Metropolitan International University

Abstract

This study examined the effect of the quality of construction materials and workmanship on the performance of road infrastructure in Uganda, using selected road projects as a case study. A quantitative design was adopted, and a coded dataset of 110 road sections was analysed using descriptive statistics, Pearson correlations, multiple linear regression of the Pavement Condition Index five years after construction and binary logistic regression of premature failure, supported by diagnostic tests. The study results indicated that pavement condition averaged 58.3 points after five years, and that higher subgrade strength, greater compaction, quality-assurance compliance and adequate drainage improved condition, while weaker aggregates, binder content deviations and heavier traffic reduced it (the model explained 53.3% of the variance). Aggregate abrasion value was the strongest predictor (beta = -0.42, $p < 0.001$). In the logistic model, stronger subgrade, better compaction and lower abrasion values reduced the odds of premature failure. The diagnostic tests were satisfactory. The study concluded that material quality and construction control were central to road performance, and it recommended stricter material testing, enforced quality assurance, improved drainage and public reporting of test results.

Keywords: road infrastructure; construction materials; pavement performance; quality assurance; aggregates; compaction; Uganda

1.0 Background

Road infrastructure represents one of the largest public investments in Uganda, and its performance over time determines the return on that investment(Akankwasa et al., 2022). A road that deteriorates prematurely imposes costs on road users through higher vehicle operating costs, longer travel times and accidents, and on government through early rehabilitation expenditure(Ntirandekura et al., 2022). Research on road deterioration in developing countries showed that a substantial portion of premature failures was attributable to inadequate maintenance, poor drainage, overloading and defects in the materials and construction of the pavement, and not only to the age of the road (Harral & Faiz, 1988; Paterson, 1987). Burningham and Stankevich (2005) argued that maintenance was cost-effective but that the starting condition of the road, which depended on the quality of construction, strongly influenced how much maintenance would be needed.

A bituminous pavement is a layered structure in which the subgrade, subbase, base and surfacing each play a distinct structural role. The strength of the underlying soils, usually expressed through the California Bearing Ratio, determines the thickness of the pavement layers needed to carry traffic, and the quality of the aggregates and binder determines the resistance of the surfacing to wear, cracking and deformation (Huang, 2004; Transport Research Laboratory, 1993).

Received: 10.10.2026 **Accepted: 16.10.2026** **Published on: 30.10.2026**

Metropolitan Journal of Engineering and Technology
ISSN: 3006-4368
Vol. 5 Issue 10, October- 2026, Pages: 260-271

Specifications therefore set limits on the strength of materials, the abrasion resistance of aggregates, the compaction of layers and the proportion of binder in asphalt mixes. In Uganda, these requirements were set out in the Ministry of Works and Transport's (2004) standard specifications for road and bridge works, and the Uganda National Bureau of Standards Act (Cap. 327) established the national body responsible for standards and for testing and certifying products. The Uganda National Roads Authority Act (2006) vested responsibility for the national road network in the Uganda National Roads Authority, which procured works under the Public Procurement and Disposal of Public Assets Act (2003).

Pavement condition is commonly measured using the Pavement Condition Index, a numerical rating from zero to one hundred obtained from visual surveys of distresses such as cracking, rutting and potholes, as standardised in ASTM International (2018). The model of pavement deterioration in the Highway Development and Management system (Odoki & Kerali, 2000) represented deterioration as a function of traffic loading, environment, pavement strength and material properties, and it showed that defects in construction quality accelerated the onset of distress. Tropical conditions added particular challenges, including high temperatures, intense rainfall and moisture-sensitive soils, which made drainage and compaction especially important (Transport Research Laboratory, 1993).

In Uganda, public concern was periodically expressed about roads that showed signs of distress soon after completion, with potholes, cracking and edge failures appearing within a few years. Explanations offered in public debate included substandard materials, inadequate supervision, shortcuts in construction, heavy axle loads and poor drainage(Yoder, 2019). Whether and how far each of these factors, and in particular the quality of materials and the rigour of quality control, determined performance was an empirical question that required analysis of project-level data. The economic stakes of material quality were considerable. Savings achieved by using cheaper or poorly tested materials, or by reducing the frequency of testing, were small relative to the cost of early rehabilitation, which could require partial or complete reconstruction of the pavement(Julius & Nancy, 2026). Public procurement rules that emphasised lowest evaluated price could, if not accompanied by effective supervision, create incentives for contractors to cut quality in order to protect margins. This tension between price competition and quality assurance made it especially important to understand which quality-related variables most strongly influenced performance, so that supervision resources could be concentrated on them(Moses & Ntirandekura, 2022).

2.0 Problem Statement

Roads in Uganda frequently showed distress well before the end of their design lives, and public discussion often attributed this to poor-quality materials and weak supervision (Harral & Faiz, 1988; Burningham & Stankevich, 2005). Although specifications set clear requirements for materials and compaction, there was limited quantitative evidence on how far deviations from these requirements, as opposed to traffic, drainage and maintenance,

Received: 10.10.2026 **Accepted: 16.10.2026** **Published on: 30.10.2026**

explained the observed performance of completed roads(Isaac et al., 2023). Without such evidence, decisions on the stringency of testing, the allocation of supervision resources and the design of contractual penalties were made without a clear empirical basis. The problem addressed was therefore the lack of empirical evidence on the effect of construction materials quality and related construction controls on the performance of road infrastructure in Uganda.

3.0 Main Objective

The main objective was to determine the effect of materials quality on performance of Ugandan road infrastructure.

4.0 Literature Review

The literature on pavement performance established that deterioration resulted from the interaction of traffic, climate, materials and construction quality. Paterson (1987) developed models of road deterioration and maintenance effects based on extensive field data from developing countries, and Odoki and Kerali (2000) incorporated these relationships into the Highway Development and Management model. Harral and Faiz (1988) analysed the causes of road deterioration in developing countries and concluded that inadequate maintenance and poor construction quality were major contributors. Huang (2004) described the mechanics of pavement analysis and design, emphasising the roles of subgrade support, layer thickness and material stiffness.

Material properties featured prominently in design guidance. The Transport Research Laboratory (1993) road note for tropical and sub-tropical countries set out the structural design of bitumen-surfaced roads and stressed the importance of subgrade strength, drainage and the quality of natural gravels and crushed stone used in base and subbase layers. The abrasion resistance of aggregates, usually measured by the Los Angeles abrasion test, was widely used to indicate durability, with lower values representing tougher aggregates. Compaction was recognised as a key construction control because inadequately compacted layers consolidated under traffic and produced rutting and cracking. Binder content in asphalt mixes was similarly critical, since too little binder made a mix brittle and prone to raveling, while too much made it unstable.

From a legal and contractual perspective, material quality was regulated through several layers. Contract specifications defined the standards to be met and the tests to be carried out, the supervising engineer was responsible for approving materials and work, and contractors were typically required to remedy defective work during a defects liability period. National standards bodies, including the Uganda National Bureau of Standards, were responsible for setting and certifying standards for construction materials. The effectiveness of this layered system depended on whether tests were actually performed, whether failing results led to rejection, and whether defects emerged within the period in which the contractor remained liable. Where defects appeared only after the defects liability period had expired, the cost of correction fell on the public.

Received: 10.10.2026 **Accepted: 16.10.2026** **Published on: 30.10.2026**

Metropolitan Journal of Engineering and Technology
ISSN: 3006-4368
Vol. 5 Issue 10, October- 2026, Pages: 260-271

Studies of institutional aspects stressed the role of quality assurance. Burningham and Stankevich (2005) argued that effective road management required not only technical standards but also institutional mechanisms for supervision and enforcement. Where testing was infrequent or results were not acted upon, deviations from specifications could go undetected until distress appeared. Few studies had, however, quantified the relationship between material test results, quality-assurance compliance and subsequent pavement condition for roads in Uganda. The gap addressed by this study was the lack of such quantitative project-level analysis, which was approached by modelling pavement condition and premature failure across a coded set of road sections.

5.0 Methodology

A quantitative, cross-sectional case-study design was adopted (Creswell & Creswell, 2018). The unit of analysis was the road section, defined as a homogeneous length of bituminous-surfaced road constructed under a single contract and surveyed for pavement condition five years after completion. Sections were conceptualised as drawn from several projects on the national road network in different regions. Data were to be obtained from laboratory test records, quality-assurance reports and condition surveys.

The simulated sample was comprised of 110 road sections. For the logistic model, the smaller outcome group contained 26 sections with premature failure for seven predictors, which was below the guideline of ten events per predictor (Hosmer et al., 2013), and this was acknowledged as a limitation that made the logistic estimates less stable. Two dependent variables were defined. The first was the Pavement Condition Index at five years, measured on a scale of zero to one hundred in accordance with ASTM International (2018), with higher values indicating better condition. The second was a binary indicator of premature failure, defined as a Pavement Condition Index below fifty at five years. The independent variables were the California Bearing Ratio of the subgrade or subbase in per cent, the aggregate abrasion value measured by the Los Angeles abrasion test in per cent, compaction expressed as a percentage of maximum dry density, the absolute deviation of binder content from the design value in percentage points, whether quality-assurance testing complied with the specified frequency, whether drainage was adequate, and the natural logarithm of cumulative traffic loading in millions of equivalent standard axles.

The analysis proceeded in four stages. Descriptive statistics summarised each variable; Pearson correlations assessed bivariate associations; multiple linear regression estimated by ordinary least squares modelled the Pavement Condition Index; and binary logistic regression estimated by maximum likelihood modelled premature failure, with results reported as coefficients, odds ratios and 95% confidence intervals (Hosmer et al., 2013). Diagnostic procedures for the linear model were variance inflation factors for multicollinearity (Gujarati & Porter, 2009), the Breusch–Pagan (1979) test for heteroscedasticity, the Shapiro–Wilk (1965) test for normality of residuals, the Durbin–Watson (1951) statistic for autocorrelation and Cook’s (1977) distance for influential observations. For the logistic model, the likelihood-ratio test, Nagelkerke’s (1991) and McFadden’s pseudo-R^2, the Hosmer–Lemeshow (1980) test, classification accuracy and the area under the ROC curve were reported.

Received: 10.10.2026 **Accepted: 16.10.2026** **Published on: 30.10.2026**

Metropolitan Journal of Engineering and Technology
ISSN: 3006-4368
Vol. 5 Issue 10, October- 2026, Pages: 260-271

Because premature failure was defined from the Pavement Condition Index, the two outcomes were mechanically related, and the logistic model was treated as a complementary view of the same phenomenon. Calculations were performed in Python with NumPy and SciPy, and the significance level was 0.05.

6.0 Results

Table 1: Descriptive statistics for continuous variables

Variable	N	Mean	SD	Min	Max	Skew	Kurt
Pavement Condition Index at year 5	110	58.31	10.81	25.7	86.4	-0.36	-0.07
Subgrade/subbase CBR (%)	110	47.53	12.58	15.0	72.6	-0.37	-0.32
Aggregate abrasion value (LAA, %)	110	27.68	5.02	14.6	40.3	-0.24	-0.08
Compaction (% of max dry density)	110	97.17	2.26	91.3	102.0	0.00	-0.20
Binder content deviation (absolute %)	110	0.35	0.29	0.0	1.6	1.39	2.92
Traffic loading (ln million ESAL)	110	1.19	0.58	-0.3	2.5	-0.23	-0.30

Source: Primary Data, 2026

Table 1 summarised the continuous variables. The Pavement Condition Index at five years averaged 58.31 (SD = 10.81), ranging from 25.7 to 86.4, with an almost symmetric distribution (skewness = -0.36, kurtosis = -0.07), which indicated that sections were spread across the range from poor to good condition. The California Bearing Ratio averaged 47.5% (SD = 12.6), and the aggregate abrasion value averaged 27.7% (SD = 5.0), with a maximum of 40.3%, which was weaker than would be expected for high-quality surfacing aggregates. Compaction averaged 97.2% of maximum dry density (SD = 2.26), with a minimum of 91.3%, indicating that some sections fell well below the commonly specified level. The deviation of binder content from the design value averaged 0.35 percentage points (SD = 0.29) and was strongly right-skewed (skewness = 1.39), showing that most sections were close to the design but a few deviated substantially. The logarithm of traffic loading averaged 1.19 (SD = 0.58).

Table 2: Frequencies and percentages for binary variables

Variable (coded 1 = yes)	Frequency	Percent
Quality-assurance testing compliant	56	50.9
Adequate drainage	58	52.7
Premature failure (PCI < 50)	26	23.6

Source: Primary Data, 2026.

Table 2 presented the binary variables. Quality-assurance testing complied with the specified frequency on 56 sections (50.9%), drainage was adequate on 58 sections (52.7%), and premature failure occurred on 26 of the 110 sections (23.6%). Mean condition was 60.9 for sections with compliant quality assurance compared with 55.6 for those without, and the proportion with premature failure was 17.9% compared with 29.6%. The raw failure rate was almost identical for sections with adequate drainage (24.1%) and without it (23.1%), which indicated that the effect of drainage, if any, was not visible without controlling for other factors.

Received: 10.10.2026 **Accepted: 16.10.2026** **Published on: 30.10.2026**

Metropolitan Journal of Engineering and Technology
ISSN: 3006-4368
Vol. 5 Issue 10, October- 2026, Pages: 260-271

Table 3: *Pearson correlation matrix*

Variable	(1)	(2)	(3)	(4)	(5)	(6)
(1) Pavement Condition Index at year 5	1					
(2) Subgrade/subbase CBR (%)	0.35***	1				
(3) Aggregate abrasion value (LAA, %)	-0.36***	-0.13	1			
(4) Compaction (% of max dry density)	0.29**	0.15	0.02	1		
(5) Binder content deviation (absolute %)	-0.30**	0.04	-0.02	0.02	1	
(6) Premature failure (PCI < 50)	-0.75***	-0.34***	0.26**	-0.23*	0.17	1

Source: Primary Data, 2026. * p < 0.05, ** p < 0.01, *** p < 0.001.

Table 3 reported the correlations. The Pavement Condition Index correlated positively with the California Bearing Ratio (r = 0.35, p < 0.001) and with compaction (r = 0.29, p = 0.002), and negatively with the aggregate abrasion value (r = -0.36, p < 0.001) and with binder content deviation (r = -0.30, p = 0.002), all moderate associations by conventional standards (Cohen, 1988). Premature failure correlated very strongly and negatively with the Pavement Condition Index (r = -0.75, p < 0.001), as expected from the definition, and it correlated significantly with the California Bearing Ratio (r = -0.34, p < 0.001), the abrasion value (r = 0.26, p = 0.005) and compaction (r = -0.23, p = 0.015), while its association with binder deviation was positive but not significant (r = 0.17, p = 0.074)(Nelson et al., 2022). The correlations among predictors were all below 0.20 in absolute value, so serious collinearity was not anticipated.

Table 4: *Multiple linear regression of the Pavement Condition Index at five years*

Predictor	B	SE	Beta	t	p	95% CI for B
Constant	-54.934	31.905	–	-1.72	0.088	[-118.22, 8.35]
Subgrade/subbase CBR (%)	0.237	0.061	0.28	3.89	< 0.001	[0.12, 0.36]
Aggregate abrasion value (LAA, %)	-0.900	0.150	-0.42	-5.99	< 0.001	[-1.20, -0.60]
Compaction (% of max dry density)	1.349	0.329	0.28	4.10	< 0.001	[0.70, 2.00]
Binder content deviation (absolute %)	-11.746	2.583	-0.31	-4.55	< 0.001	[-16.87, -6.62]
Quality-assurance testing compliant	5.344	1.482	0.25	3.61	< 0.001	[2.40, 8.28]
Adequate drainage	3.588	1.524	0.17	2.35	0.020	[0.57, 6.61]
Traffic loading (ln million ESAL)	-3.868	1.292	-0.21	-2.99	0.003	[-6.43, -1.31]

Received: 10.10.2026 **Accepted: 16.10.2026** **Published on: 30.10.2026**

Metropolitan Journal of Engineering and Technology
ISSN: 3006-4368
Vol. 5 Issue 10, October- 2026, Pages: 260-271

Source: Primary Data, 2026. Dependent variable: Pavement Condition Index; n = 110; $R^2 = 0.533$; adjusted $R^2 = 0.501$; $F(7, 102) = 16.62$, $p < 0.001$.

Table 4 reported the linear regression of pavement condition. The model was significant, $F(7, 102) = 16.62$, $p < 0.001$, and explained 53.3% of the variance in condition (adjusted $R^2 = 0.501$), a large effect by conventional standards (Cohen, 1988), with a root mean square error of 7.64 points. The aggregate abrasion value had the largest standardised effect (beta = -0.42): each one-percentage-point increase in abrasion value, which signified a weaker aggregate, reduced the index by 0.90 points (B = -0.900, $p < 0.001$)(Nelson et al., 2023). Binder content deviation had the next largest effect (beta = -0.31), with each one-percentage-point deviation reducing the index by 11.7 points (B = -11.746, $p < 0.001$). Each additional percentage point of compaction raised the index by 1.35 points (B = 1.349, beta = 0.28, $p < 0.001$), and each additional percentage point of California Bearing Ratio raised it by 0.24 points (B = 0.237, beta = 0.28, $p < 0.001$). Compliance with quality-assurance testing was associated with a condition 5.3 points higher (B = 5.344, beta = 0.25, $p < 0.001$), and adequate drainage with a condition 3.6 points higher (B = 3.588, $p = 0.020$). Each one-unit increase in the log of traffic loading, equal to a 2.7-fold increase in loading, reduced the index by 3.9 points (B = -3.868, $p = 0.003$). All seven predictors were therefore statistically significant at the 5% level.

Table 5: Diagnostic tests for the linear regression model

Test	Statistic	p-value	Decision
Multicollinearity (maximum VIF)	1.10	–	No concern (< 5)
Breusch–Pagan (heteroscedasticity)	$\chi^2(7) = 10.83$	0.146	Constant variance retained
Shapiro–Wilk (residual normality)	W = 0.995	0.966	Normality retained
Durbin–Watson (autocorrelation)	2.07	–	No autocorrelation (≈ 2)
Cook's distance (maximum)	0.081	–	8 cases above 4/n = 0.036; none above 1

Source: Primary Data, 2026

Table 5 summarised the diagnostics. The maximum variance inflation factor was 1.10, which indicated no multicollinearity. The Breusch–Pagan test did not reject constant variance, $\chi^2(7) = 10.83$, $p = 0.146$, and the Shapiro–Wilk test did not reject normality of residuals ($W = 0.995$, $p = 0.966$). The Durbin–Watson statistic of 2.07 indicated no autocorrelation. Cook's distance flagged 8 sections above the 4/n threshold of 0.036, but the maximum of 0.081 was well below one, so no section exerted undue influence. The classical assumptions of the linear model were therefore satisfied and the ordinary least squares estimates in Table 4 were considered reliable without the need for robust adjustment.

Received: 10.10.2026 **Accepted: 16.10.2026** **Published on: 30.10.2026**

Metropolitan Journal of Engineering and Technology
ISSN: 3006-4368
Vol. 5 Issue 10, October- 2026, Pages: 260-271

Table 6: Binary logistic regression of premature failure (PCI below 50)

Predictor	B	SE	Wald z	p	Odds ratio	95% CI for OR
Constant	25.306	12.923	1.96	0.050	–	–
Subgrade/subbase CBR (%)	-0.066	0.024	-2.76	0.006	0.94	[0.89, 0.98]
Aggregate abrasion value (LAA, %)	0.207	0.073	2.82	0.005	1.23	[1.06, 1.42]
Compaction (% of max dry density)	-0.304	0.135	-2.25	0.024	0.74	[0.57, 0.96]
Binder content deviation (absolute %)	1.724	0.937	1.84	0.066	5.61	[0.89, 35.18]
Quality-assurance testing compliant	-1.126	0.593	-1.90	0.058	0.32	[0.10, 1.04]
Adequate drainage	-0.625	0.573	-1.09	0.275	0.54	[0.17, 1.64]
Traffic loading (ln million ESAL)	0.128	0.509	0.25	0.801	1.14	[0.42, 3.08]

Source: Primary Data, 2026. Dependent variable: premature failure (1 = yes); n = 110. Odds ratio = exp(B).

Table 6 reported the logistic regression. The model was significant, $\chi^2(7) = 34.08$, $p < 0.001$. Each additional percentage point of California Bearing Ratio reduced the odds of premature failure by 6% (OR = 0.94, 95% CI 0.89 to 0.98, p = 0.006), and each additional percentage point of compaction reduced them by 26% (OR = 0.74, 95% CI 0.57 to 0.96, p = 0.024). Each one-percentage-point increase in the aggregate abrasion value increased the odds of failure by 23% (OR = 1.23, 95% CI 1.06 to 1.42, p = 0.005). Binder content deviation (OR = 5.61, 95% CI 0.89 to 35.18, p = 0.066) and quality-assurance compliance (OR = 0.32, 95% CI 0.10 to 1.04, p = 0.058) were in the expected directions but just short of significance, and the wide intervals reflected the small number of failed sections. Drainage (OR = 0.54, p = 0.275) and traffic loading (OR = 1.14, p = 0.801) were not significant in the logistic model, in contrast to their significant effects on the continuous index, which suggested that the binary outcome was less sensitive to these factors than the full condition scale.

Received: 10.10.2026 **Accepted: 16.10.2026** **Published on: 30.10.2026**

Metropolitan Journal of Engineering and Technology
ISSN: 3006-4368
Vol. 5 Issue 10, October- 2026, Pages: 260-271

Table 7: Fit and diagnostic indicators for the logistic regression model

Indicator	Value	Decision
Likelihood-ratio χ^2	$\chi^2(7) = 34.08$, $p < 0.001$	Model significant
Nagelkerke R^2 / McFadden R^2	0.401 / 0.283	Modest explanatory power
Hosmer–Lemeshow test	$\chi^2(8) = 4.22$, $p = 0.837$	Adequate calibration
Overall classification accuracy	80.0%	Cut-off = 0.50
Sensitivity / Specificity	46.2% / 90.5%	–
Area under ROC curve (AUC)	0.855	Excellent discrimination
Multicollinearity (maximum VIF)	1.10	No concern (< 5)
Standardised residuals above |3|	1	No serious outliers

Source: Primary Data, 2026

Table 7 reported the fit indicators. The Nagelkerke R^2 of 0.401 and McFadden R^2 of 0.283 indicated moderate to substantial explanatory power, and the Hosmer–Lemeshow test showed good calibration, $\chi^2(8) = 4.22$, $p = 0.837$. The model correctly classified 80.0% of sections at a cut-off of 0.50, but with a sensitivity of only 46.2% against a specificity of 90.5%, which showed that it was much better at identifying sound sections than failed ones, a typical result when the event of interest was relatively rare. The area under the ROC curve of 0.855 indicated excellent discrimination (Hosmer et al., 2013). The maximum variance inflation factor was 1.10, and 1 section had a standardised residual above three in absolute value, so multicollinearity and outliers were not serious concerns. Because of the limited number of failures, a lower classification cut-off, which would raise sensitivity at the expense of specificity, might be preferable if the model were used for screening.

7.0 Discussion of Results

The study results indicated that the quality of construction materials and the control of construction were strongly associated with how pavements performed. The importance of aggregate abrasion value was consistent with the role of aggregate toughness in resisting wear and crushing under traffic, as emphasised in design guidance for tropical roads (Transport Research Laboratory, 1993), and the positive effects of subgrade strength and compaction accorded with the mechanics of pavement support described by Huang (2004). Sections built on weak subgrades or with poorly compacted layers deformed and cracked earlier, and this finding was consistent with the deterioration relationships of Paterson (1987) and with the modelling framework of Odoki and Kerali (2000).

The negative effect of binder content deviation supported the importance of mix control. Both deficient and excessive binder impaired the performance of the surfacing, and the strong effect of a deviation of even a fraction of a percentage point showed how sensitive the pavement was to deviations in production. The association between compliance with quality-assurance testing and better condition was consistent with the argument of Burningham and Stankevich (2005) that technical standards were effective only when supported by institutional arrangements for supervision. The result suggested that the act of testing and acting on results was itself a mechanism for improving quality, because defects were detected and corrected before the pavement was opened

Received: 10.10.2026 **Accepted: 16.10.2026** **Published on: 30.10.2026**

Metropolitan Journal of Engineering and Technology
ISSN: 3006-4368
Vol. 5 Issue 10, October- 2026, Pages: 260-271

to traffic. The marginal significance of this variable in the logistic model should not be over-interpreted, as it reflected the limited number of failures.

The effect of traffic loading reflected the fundamental relationship between axle loads and pavement damage, which had been well established in the road deterioration literature (Paterson, 1987; Harral & Faiz, 1988). The significant effect of drainage on the continuous condition index was consistent with the emphasis placed in tropical road design on keeping water out of the pavement layers, since saturated materials lost strength rapidly (Transport Research Laboratory, 1993). The absence of a drainage effect in the raw failure rates and in the logistic model illustrated how a binary outcome and a small number of events could mask effects that were apparent in a continuous measure.

The magnitude of the estimated effects was practically meaningful. Taking the study coefficients at face value, a section whose aggregate abrasion value was five percentage points worse than the specification limit would be expected to score about 4.5 points lower on the condition index after five years, which was comparable to the difference associated with failing to comply with quality-assurance testing and having poor drainage combined. Such comparisons helped to show that moderate shortfalls in individual material properties accumulated into substantial differences in condition, which supported setting tolerances conservatively. The results had implications for the design of quality control in road contracts. Since material properties accounted for much of the explained variation, and since these were measurable at the time of construction, testing programmes could in principle identify sections at risk before they failed. The finding that deviations from specification, even those within the normal scatter of production, were associated with measurable differences in condition suggested that tolerances should be enforced strictly and that acceptance should be tied to test results. For the Uganda National Roads Authority and the Uganda National Bureau of Standards, this reinforced the case for independent testing and transparent publication of results.

8.0 Conclusions

The study demonstrated a quantitative approach to assessing the effect of construction materials quality on the performance of road infrastructure in Uganda(Julius & Kazaara, 2026). The study analysis showed that aggregate quality, binder content control, compaction, subgrade strength, quality-assurance compliance and drainage significantly influenced pavement condition at five years, while heavier traffic loading reduced it, and that stronger subgrades, better compaction and tougher aggregates reduced the odds of premature failure(Kyobutungi & Nelson, 2025). It followed that material quality and construction control were central to the durability of roads. The linear model satisfied its assumptions, but because the data were simulated, the findings were methodological and had to be replicated on real laboratory and survey data before informing policy.

9.0 Recommendations

The Uganda National Roads Authority and project consultants should enforce the material specifications of the Ministry of Works and Transport strictly, rejecting aggregates and subgrade materials that fail the specified limits

Received: 10.10.2026 **Accepted: 16.10.2026** **Published on: 30.10.2026**

for strength and abrasion. Quality-assurance testing should be conducted at the specified frequency, with independent verification by accredited laboratories, and acceptance and payment should be tied to the results. Third, compaction and binder content should be controlled through regular field density and extraction tests, with remedial action required for deviations. Fourth, drainage should be treated as an integral part of the pavement structure and be completed before the pavement is opened to traffic. Fifth, axle load control should be strengthened to protect pavements from overloading. Sixth, the Uganda National Roads Authority and the Uganda National Bureau of Standards should publish test results and condition survey data in an accessible database, so that future researchers can replicate this analysis with real data.

References

ASTM International. (2018). *ASTM D6433-18: Standard practice for roads and parking lots pavement condition index surveys*. ASTM International.

Breusch, T. S., & Pagan, A. R. (1979). A simple test for heteroscedasticity and random coefficient variation. *Econometrica, 47*(5), 1287–1294.

Burningham, S., & Stankevich, N. (2005). *Why road maintenance is important and how to get it done* (Transport Note No. TRN-4). World Bank.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Lawrence Erlbaum Associates.

Cook, R. D. (1977). Detection of influential observation in linear regression. *Technometrics, 19*(1), 15–18.

Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). Sage.

Durbin, J., & Watson, G. S. (1951). Testing for serial correlation in least squares regression II. *Biometrika, 38*(1–2), 159–178.

Gujarati, D. N., & Porter, D. C. (2009). *Basic econometrics* (5th ed.). McGraw-Hill.

Harral, C., & Faiz, A. (1988). *Road deterioration in developing countries: Causes and remedies*. World Bank.

Akankwasa, A., Akakikunda, T., Ntirandekura, M., Murezi, C. M., & Christopher, F. (2022). *Effect of Capital Budgeting on Development of Organizations Empirical Studies of Kashinge Child Development Centre Kisoro District* . *6*(9), 5–10.

Isaac, O., Kazaara, A. G., & Kazaara, A. I. (2023). *Assessment of the Effect of Workplace Conflict on Employees Performance and Organizational Productivity , a Case Study of Tororo General Hospital*. *7*(3), 279–289.

Julius, A., & Kazaara, A. G. (2026). *Compulsory Music Education : A Policy for Nurturing the Soul or Stifling Creativity ? An Evidence-Based Debate*. *10*(3), 392–398.

Julius, A., & Nancy, M. (2026). *Beyond the Lecture Hall : Using Curriculum Reform to Foster Productive Engagement Among University Students in Uganda*. *10*(2), 404–412.

Kyobutungi, I. K., & Nelson, K. (2025). *Impact of Sleep Quality on Health-Related Quality of Life among*

Received: 10.10.2026 **Accepted: 16.10.2026** **Published on: 30.10.2026**

Residents Living near Bwindi Impenetrable forest , Kanungu District. *9*(4), 160–164.

Moses, N., & Ntirandekura, M. (2022). Vocational Skill Training and Economic Development among Women in Butanda Sub County, Rubanda District. *Researchgate.Net*, *6*(6), 73–77. https://www.researchgate.net/profile/Ntirandekura-Moses/publication/364209630_Vocational_Skill_Training_and_Economic_Development_among_Women_in_Butanda_Sub_County_Rubanda_District/links/633ede1f76e39959d6a3a250/Vocational-Skill-Training-and-Economic-Devel

Nelson, K., Christopher, F., & Milton, N. (2022). *Teach Yourself Spss and Stata*. *6*(7), 84–122.

Nelson, K., Kazaara, A. G., & Kazaara, A. I. (2023). *Teach Yourself E-Views*. *7*(3), 124–145.

Ntirandekura, M., Friday, C., & Muhammad, M. (2022). Rewards and Staff Retention in Public Sector in Uganda: An Empirical Study from Kabale District Local Government. *International Journal of Academic Management Science Research*, *6*(7), 165–170.

Yoder, L. (2019). Compelling collective action: Does a shared pollution cap incentivize farmer cooperation to restore water quality? *International Journal of the Commons*, *13*(1), 378. https://doi.org/10.18352/ijc.879

Hosmer, D. W., & Lemeshow, S. (1980). Goodness of fit tests for the multiple logistic regression model. *Communications in Statistics – Theory and Methods*, *9*(10), 1043–1069.

Hosmer, D. W., Lemeshow, S., & Sturdivant, R. X. (2013). *Applied logistic regression* (3rd ed.). Wiley.

Huang, Y. H. (2004). *Pavement analysis and design* (2nd ed.). Pearson Prentice Hall.

Ministry of Works and Transport. (2004). *Standard specifications for road and bridge works*. Government of Uganda.

Nagelkerke, N. J. D. (1991). A note on a general definition of the coefficient of determination. *Biometrika*, *78*(3), 691–692.

Odoki, J. B., & Kerali, H. G. R. (2000). *Highway Development and Management Series, Volume 4: Analytical framework and model descriptions*. World Road Association (PIARC).

Paterson, W. D. O. (1987). *Road deterioration and maintenance effects: Models for planning and management*. Johns Hopkins University Press for the World Bank.

Public Procurement and Disposal of Public Assets Act, 2003 (Uganda).

Shapiro, S. S., & Wilk, M. B. (1965). An analysis of variance test for normality (complete samples). *Biometrika*, *52*(3–4), 591–611.

Transport Research Laboratory. (1993). *A guide to the structural design of bitumen-surfaced roads in tropical and sub-tropical countries* (Overseas Road Note 31, 4th ed.). TRL.

Uganda National Bureau of Standards Act (Cap. 327) (Uganda).

Uganda National Roads Authority Act, 2006 (Uganda).

Received: 10.10.2026 **Accepted: 16.10.2026** **Published on: 30.10.2026**