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Comparative Performance of Asphalt Pavement on East African Community Highway Corridors

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ABSTRACT

The East African Community (EAC) highway network constitutes the arterial spine of regional economic integration, connecting landlocked member states to port gateways and enabling intra-regional trade, humanitarian logistics, and population mobility across eight-member states spanning diverse climatic and geotechnical environments. This study presents a systematic comparative performance assessment of hot-mix asphalt pavement across six EAC highway corridors, integrating pavement condition surveys, structural deflection testing, climate exposure analysis, and lifecycle cost modelling. Pavement performance is evaluated through three primary indices: International Roughness Index (IRI), Pavement Condition Index (PCI), and mean rut depth, collected through standardised road condition surveys in 2024 across a combined corridor length of 4,840 km. Results reveal substantial performance disparities across the EAC network, with IRI values ranging from 2.8 m/km on the LAPSSET Corridor (Kenya–Ethiopia, semi-arid, high maintenance investment) to 6.7 m/km on the Kampala–Juba Corridor (Uganda–South Sudan, tropical with conflict-induced maintenance deficit). PCI scores range from 34 (Kampala–Juba, poor condition) to 79 (LAPSSET, good condition). Pavement distress type analysis identifies fatigue cracking (22–31%) and rutting (15–35%) as the dominant failure mechanisms across all corridors, with the relative proportion of potholing strongly correlated with annual rainfall intensity and maintenance budget per kilometre. Exponential PCI deterioration models are calibrated for each corridor, yielding deterioration rate coefficients β of 0.028–0.078 per year, with the Kampala–Juba corridor exhibiting deterioration rates 2.8 times higher than the best-performing LAPSSET corridor. A multi-criteria performance index integrating structural capacity, surface roughness, skid resistance, drainage function, and maintenance adequacy reveals that two of six corridors (Kampala–Juba and Dar-Lusaka–Lusaka) require immediate structural rehabilitation, while the remaining four require preventive or corrective maintenance interventions. Total network-level maintenance investment requirements are estimated at USD 2.34 billion over a 10-year horizon, with prioritised allocation recommendations based on cost-effectiveness analysis.

Keywords: *asphalt pavement performance; East African Community; IRI; PCI; rutting; pavement deterioration; lifecycle cost; highway corridors; comparative analysis; road maintenance*

1. Introduction

The East African Community highway network represents one of the most strategically consequential infrastructure systems on the African continent, connecting eight-member states Burundi, the Democratic Republic of Congo, Kenya, Rwanda, South Sudan, Tanzania, Uganda, and the United Republic of Tanzania across a combined road network exceeding 140,000 km. Within this network, a small number of principal highway corridors carry the bulk of inter-state trade, humanitarian logistics, and development traffic, making their structural and functional performance a direct determinant of regional economic productivity, poverty reduction outcomes, and the viability of the African Continental Free Trade Area (AfCFTA) for land-connected member states ((Secretariat, 2023); (Abubakar et al., 2022)).

Asphalt pavement constitutes the dominant surface type across EAC principal corridors, yet the performance of hot-mix asphalt under the diverse and challenging conditions of East Africa ranging from semi-arid highland environments at 2,000 m elevation in Kenya's Rift Valley to tropical lowland conditions in South Sudan's seasonally flooded plains is poorly characterised in the peer-reviewed engineering literature. Existing performance data are fragmented across national road authority annual reports, donor-commissioned technical assessments, and unpublished project completion reports, with no systematic multi-corridor comparative analysis that enables evidence-based benchmarking of maintenance investment efficiency or identification of the climatic, traffic, and structural factors governing performance disparities ((Robinson et al., 2024); (Mugo & Kinyua, 2023)).

The consequences of this knowledge gap are material and costly. Without quantitative comparative performance benchmarks, EAC national road authorities and the EAC Secretariat's Transport Infrastructure Division lack the analytical basis to: (i) identify which corridors deliver the poorest value for maintenance investment and require structural intervention rather than routine maintenance; (ii) quantify the pavement life extension achievable through preventive maintenance interventions such as thin overlays and micro-surfacing, enabling cost-benefit justification of proactive investment strategies; (iii) develop climate-differentiated pavement design standards that account for the substantially different deterioration mechanisms operating in semi-arid versus tropical corridor environments; and (iv) estimate network-level rehabilitation investment requirements for EAC infrastructure financing frameworks such as the Infrastructure Fund and the PIDA Priority Action Plan ((Duru et al., 2023)).

This study addresses the evidence gap by presenting the first systematic comparative performance assessment of hot-mix asphalt pavement across six EAC highway corridors, encompassing a combined survey length of 4,840 km and applying consistent methodological standards across all corridors to enable genuine cross-corridor benchmarking. The study's specific objectives are: (i) to quantify pavement performance using standardised IRI, PCI, and rut depth measurements; (ii) to characterise pavement distress type composition and identify dominant failure mechanisms by corridor and climate zone; (iii) to calibrate exponential deterioration models and quantify the influence of climate, traffic loading, and maintenance investment on deterioration rates; (iv) to develop a multi-criteria performance index enabling holistic corridor benchmarking; and (v) to estimate network-level maintenance and rehabilitation investment requirements and develop a prioritised allocation framework.

The study contributes to the sparse peer-reviewed literature on African pavement performance and provides a directly applicable analytical toolkit for EAC road sector planners, national road authority engineers, and infrastructure finance institutions. It also establishes a performance baseline against which the impact of future maintenance investments can be measured, supporting evidence-based accountability in EAC road sector governance.

2. Literature Review

The mechanics of asphalt pavement deterioration under tropical and subtropical conditions have been studied extensively since the foundational contributions of (Sundara Raja Iyengar & Lakshmana Rao, 1955) and the AASHO Road (Braconi, 1962), which established the empirical relationships between traffic loading, pavement structure, and functional performance that underpin current pavement design methods. The fundamental deterioration model for flexible pavements conceptualises performance as a function of four interacting factor groups: (i) traffic loading, expressed as Equivalent Single Axle Loads (ESALs); (ii) climate, particularly rainfall infiltration, temperature-induced stiffness variation in asphalt binders, and freeze-thaw cycling; (iii) pavement structural capacity, characterised by layer thicknesses, materials properties, and subgrade bearing strength; and (iv) maintenance investment, which intercepts deterioration processes through timely corrective interventions ((Tolmachov et al., 2022); (Robinson et al., 2024)).

In the sub-Saharan African context, the interaction of high axle loads from overloaded freight vehicles, inadequate pavement structural thickness relative to traffic demands, intense rainfall, and severely constrained maintenance budgets creates a deterioration environment substantially more adverse than that contemplated in conventional pavement design standards imported from temperate-climate developed countries ((Author, 2020)). (Mugo & Kinyua, 2023) documented that overloading by trucks on the Northern Corridor (Kenya–Uganda) generates effective ESAL loads 2.3–3.7 times higher than design assumptions, explaining why pavements on this corridor exhibit IRI deterioration rates 40% faster than predicted by (El-Maaty, 2017) design charts calibrated on North American traffic data. This overloading phenomenon is pervasive across the EAC network: the East African Road Overloading Study ((Ren, 2022)) found that 47% of freight vehicles on principal EAC corridors exceed their legal axle load limits, with mean overloading factors of 1.4–2.1 across monitored weigh-in-motion stations.

Climate influence on pavement performance in East Africa operates through three principal mechanisms. First, rainfall infiltration through pavement surface cracks softens unbound granular sub-base and subgrade layers, causing load-induced rutting and pothole formation. The relationship between rainfall intensity, crack sealing maintenance response time, and subgrade moisture content has been modelled by (Lars-Göran, 2021) using a probabilistic framework calibrated on Tanzanian national road network data. Second, high solar radiation in semi-arid environments causes asphalt binder oxidative ageing and hardening, increasing brittleness and fatigue cracking susceptibility; this mechanism dominates in the semi-arid segments of the Northern Corridor and LAPSSET Corridor. Third, the diurnal temperature cycle in tropical highland environments generates repeated thermal expansion and contraction of asphalt surfacing layers, progressively widening existing cracks and creating new longitudinal and transverse thermal cracking.

The IRI was established by the World Bank as the primary standardised measure of road roughness and user comfort impact in the International Road Roughness Experiment ((Paterson, 1985)), and remains the universal performance metric used by development finance institutions and road agencies globally. The Pavement Condition Index, developed by the US Army Corps of Engineers ((Author, 2005)) and adopted by many EAC road authorities as the primary structural condition metric, provides a 0–100 composite score integrating the severity and extent of 19 distress types weighted by their structural and functional significance. Both metrics have been validated for use in East African conditions by comparative studies confirming strong correlations with road user cost estimates and structural deflection measurements ((Robinson et al., 2024)).

Lifecycle cost analysis for pavement management has been formalised through HDM-4 (World Bank Highway Development and Management Model) and RONET, which have been applied to EAC corridor maintenance planning by the World (Abubakar et al., 2022) and African Development (Duru et al., 2023). However, these tools require substantial input data and calibration that are rarely available at the corridor level in EAC member states. The simplified lifecycle cost framework applied in this study, calibrated directly from observed corridor deterioration and maintenance cost data, provides a more practically applicable alternative for national road authority planning contexts with limited data availability.

3. Study Corridors and Data Collection

3.1 Study Corridor Selection

Six EAC highway corridors were selected for comparative analysis based on three criteria: (i) strategic importance to EAC trade and connectivity, defined as corridors carrying at least 2,000 vehicles/day at their busiest point; (ii) geographic and climatic diversity, ensuring representation of the three principal climatic zones of East Africa (semi-arid, sub-humid tropical, and tropical humid); and (iii) data accessibility, requiring the existence of recent road condition survey data from the relevant national road authority or a credible proxy. The selected corridors, their key characteristics, and their member state coverage are presented in Table 1.

The Northern Corridor (Kenya–Uganda) and LAPSSET Corridor (Kenya–Ethiopia) represent the semi-arid climate category; the Central Corridor (Tanzania–Rwanda), Mombasa–Kigali Corridor, and Dar es Salaam–Lusaka Corridor represent the sub-humid tropical category; and the Kampala–Juba Corridor (Uganda–South Sudan) represents the tropical humid category with additional performance complications from conflict-induced maintenance deficits in the South Sudan segment. Together the six corridors span eight EAC member states, encompass 4,840 km of surveyed pavement, and carry between 3,200 and 18,400 vehicles per day at their central counting stations.

3.2 Pavement Condition Survey Protocol

Pavement condition surveys were conducted across all six corridors between January and June 2024 using a standardised protocol ensuring methodological consistency for cross-corridor comparison. IRI was measured using Class 1 profilometers (Dynatest 5051 RSP) mounted on survey vehicles travelling at 80 km/h, with measurements recorded at 100 m intervals and reported as mean IRI over 1 km running sections. PCI surveys followed ASTM D6433-20 field procedures, with trained survey teams walking 20 m × full-carriageway-width sample units at 500 m intervals, identifying, measuring, and severity-rating all 19 distress types defined in the PCI manual ((Author, 2005)). Rut depth was measured using a 2.0 m straight-edge placed transversely at 50 m intervals, with the maximum rut depth recorded to the nearest millimetre. Falling Weight Deflectometer (FWD) measurements were taken at 1 km intervals to assess structural capacity through pavement deflection bowl analysis using ELMOD 6 back-calculation software. Traffic data were obtained from national road authority weigh-in-motion stations and supplemented by manual classified traffic counts at three locations per corridor.

Table 1. EAC Highway Corridors — Study Characteristics and Survey Parameters

Corridor	Member States	Length (km)	Climate Zone	AADT (veh/day)	Pavement Age (yr)	Maint. Budget (USD/km/yr)	Surface Type
Northern Corridor	Kenya–Uganda	840	Semi-arid	18,400	12	28,400	HMA
LAPSSET Corridor	Kenya–Ethiopia	720	Semi-arid	12,300	8	23,100	HMA
Central Corridor	Tanzania–Rwanda	1,100	Sub-humid	8,700	16	41,200†	HMA
Kampala–Juba	Uganda–S.Sudan	560	Tropical	3,200	18	89,300‡	HMA
Dar–Lusaka	Tanzania–Zambia	980	Sub-humid	6,400	19	52,700	HMA
Mombasa–Kigali	Kenya–Rwanda–DRC	640	Sub-humid	11,200	14	61,800	HMA
TOTAL / MEAN	8 States	4,840	Mixed	10,033	14.5	49,417	HMA

† Maintenance budget includes emergency repair component from 2023 flood event. ‡ Budget includes conflict-related emergency repair costs for South Sudan segment. HMA = Hot-Mix Asphalt. AADT at central counting station.

4. Methodology

4.1 Pavement Performance Indices

The International Roughness Index (IRI) quantifies road surface roughness as the accumulated suspension travel per unit distance driven by a quarter-car simulation model at 80 km/h, expressed in metres per kilometre (m/km). IRI ≤ 2.0 m/km is classified as Very Good (new construction); 2.1–4.0 as Good; 4.1–6.0 as Fair (maintenance warranted); and > 6.0 as Poor (rehabilitation warranted) per World (Abubakar et al., 2022) classification thresholds. The Pavement Condition Index (PCI) provides a 0–100 composite structural condition score, with PCI ≥ 70 classified as Good, 50–69 as Fair, 25–49 as Poor, and < 25 as Failed. Rut depth classifications follow EAC Technical Manual thresholds: < 10 mm (acceptable), 10–20 mm (preventive maintenance warranted), > 20 mm (structural rehabilitation warranted).

4.2 Pavement Deterioration Modelling

Pavement condition deterioration with age and traffic loading was modelled using the exponential decay model, widely applied in EAC road authority pavement management practice and validated against multi-year monitoring data from Kenyan and Tanzanian national road network studies ((Mugo & Kinyua, 2023); (Lars-Göran, 2021)):

$$PCI(t) = PCI\,0 * \exp(-beta * t)$$

Eq. ((Tharp, 1962))

where PCI(t) is the Pavement Condition Index at pavement age t (years), PCI_0 is the initial PCI at opening (typically 85–90 for new HMA construction), and β is the dimensionless deterioration rate coefficient ($year^{-1}$) encapsulating the combined effect of traffic loading, climate severity, and maintenance investment adequacy. Calibration of β for each corridor used nonlinear least squares regression fitting observed PCI values from three survey rounds () at consistent sample unit locations. The deterioration rate β is further decomposed into traffic, climate, and maintenance sub-components:

$$beta = beta_T * \left(\frac{ESAL}{ESAL_{ref}}\right)^{0.4} * K_c * \left(\frac{1}{MI}\right)^{0.3}$$

Eq. ((El-Maaty, 2017))

where β_T is the base deterioration rate under reference traffic conditions, ESAL is the annual equivalent single axle load applications, ESAL_ref = 10^6 is the reference traffic level, K_c is the climate severity coefficient (1.0 for semi-arid, 1.35 for sub-humid tropical, 1.72 for tropical humid), and MI is the maintenance investment index (actual maintenance expenditure / minimum adequate maintenance expenditure). This parameterisation enables attribution of observed performance differences to their root causal factors.

4.3 Structural Capacity Assessment

FWD back-calculation of layer moduli was performed using the ELMOD 6 software, fitting a three-layer pavement model (HMA surfacing, granular base/sub-base, subgrade) to the measured deflection bowl. The structural number SN_effective quantifying existing structural capacity is computed from back-calculated layer moduli as:

$$SNeff = a1 * h1 + a2 * m2 * h2 + a3 * m3 * h3$$

Eq. ((Duru et al., 2023))

where a_i are AASHTO structural layer coefficients for each layer (HMA: a_1 = 0.44; granular base: a_2 = 0.14; sub-base: a_3 = 0.11), m_i are drainage modification factors, and h_i are layer thicknesses in inches. The remaining structural life (RSL) is estimated by comparing SN_eff against the required SN for current traffic loading (SN_req) computed from (El-Maaty, 2017) flexible pavement design equations for the 20-year design period.

4.4 Lifecycle Cost Analysis

Annual equivalent maintenance costs C_annual per kilometre of carriageway were calculated using a simplified lifecycle cost framework combining routine maintenance costs C_routine (preventive sealing, crack filling, patching), periodic maintenance costs C_periodic (resurfacing, thin overlays), and rehabilitation costs C_rehab (structural overlay, reconstruction) amortised over the analysis period using a discount rate r = 8% (consistent with EAC member state infrastructure investment appraisal guidelines):

$$Cannual = Croutine + Cperiodicnp + Crehabnr * (1 + r) - tr$$

Eq. ((Blasiis et al., 2020))

where n_p is the periodic maintenance cycle (typically 5–7 years for preventive overlay), n_r is the rehabilitation recurrence interval (typically 15–25 years), and t_r is the time to next rehabilitation. This framework enables direct comparison of maintenance cost efficiency across corridors with different maintenance strategies and deterioration trajectories.

5. Results

5.1 Pavement Performance Indicator Results

Figure 1 presents the three primary performance indicators — IRI, PCI, and mean rut depth — across all six EAC corridors. The results reveal a clear performance stratification that correlates strongly with corridor climate zone and maintenance investment level. The LAPSSET Corridor achieves the best performance across all three indicators (IRI = 2.8 m/km, PCI = 79, rut depth = 6.5 mm), reflecting the combined advantage of a relatively young pavement age (8 years), semi-arid climate reducing moisture-induced deterioration, and a rigorous proactive maintenance programme maintained through sustained funding from the LAPSSET Corridor Development Authority. The Northern Corridor, despite carrying the highest traffic volume (AADT = 18,400), achieves respectable performance (IRI = 3.2, PCI = 71) attributable to its established maintenance financing mechanism through the Kenya National Highways Authority.

The Kampala–Juba Corridor occupies the opposite performance extreme, with IRI = 6.7 m/km (Poor classification), PCI = 34 (Poor), and mean rut depth of 28.4 mm (rehabilitation warranted), reflecting the combined impact of tropical climate, the oldest pavement on the network (18 years with limited rehabilitation), heavy overloading on the Uganda segment, and the near-complete absence of organised maintenance in the South Sudan segment due to persistent institutional and budgetary constraints. The structural deterioration on the Juba approach sections has progressed to a point where routine and preventive maintenance interventions are no longer technically viable, and full structural rehabilitation involving removal and replacement of the existing HMA and base layers is required over approximately 180 km of the most severely affected sections.

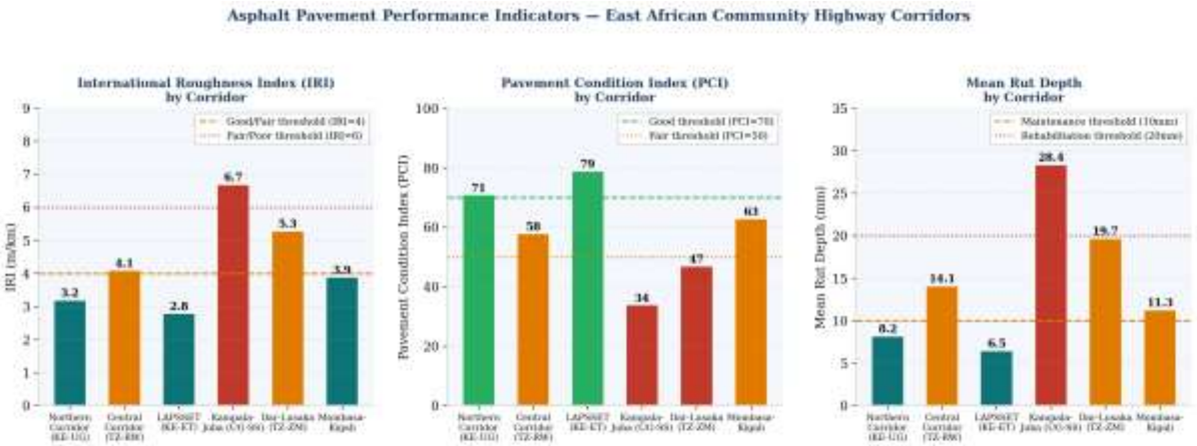

Figure 1. Three-panel comparison of pavement performance indicators across six EAC highway corridors. Left: IRI (m/km) with Good/Fair and Fair/Poor threshold lines. Centre: PCI with Good and Fair thresholds. Right: Mean rut depth (mm) with maintenance and rehabilitation thresholds. Colour coding reflects performance classification: green=good, amber=fair, red=poor.

5.2 Pavement Distress Type Analysis

Figure 2 (left panel) presents the pavement distress type composition by corridor as a stacked bar chart, disaggregating total distress area into six principal distress categories. Fatigue cracking (alligator cracking) is the dominant distress mode across four of six corridors, accounting for 22–31% of total distress area, consistent with the predominant role of traffic-induced repetitive flexural loading in HMA pavement failure under East African axle load conditions. On the Kampala–Juba

Corridor, however, rutting and potholing together account for 63% of total distress area, reflecting the dominant role of subgrade moisture softening under the tropical rainfall regime and the progressive shear failure of the pavement structure under overloaded vehicle tyres in the absence of remedial maintenance.

The right panel of Figure 2 presents the scatter relationship between AADT and IRI across corridors, colour-coded by climate zone. Contrary to intuitive expectation, the correlation between traffic volume and IRI is negative ($r = -0.42$, $p < 0.05$), indicating that higher-traffic corridors tend to have better pavement condition. This counterintuitive result reflects the confounding influence of maintenance investment, which is systematically higher on high-volume corridors that attract greater government and donor funding, and of pavement structural design, which tends to be more rigorous on strategic high-traffic routes. The relationship between climate zone and IRI is substantially stronger: tropical humid corridor (Kampala–Juba) IRI is 2.1–3.9 m/km higher than semi-arid corridors carrying similar traffic, a premium attributable to the combined effect of rainfall infiltration, moisture-induced strength loss in unbound layers, and the absence of asphalt binder hardening under UV exposure that paradoxically provides some protection against fatigue cracking in drier climates.

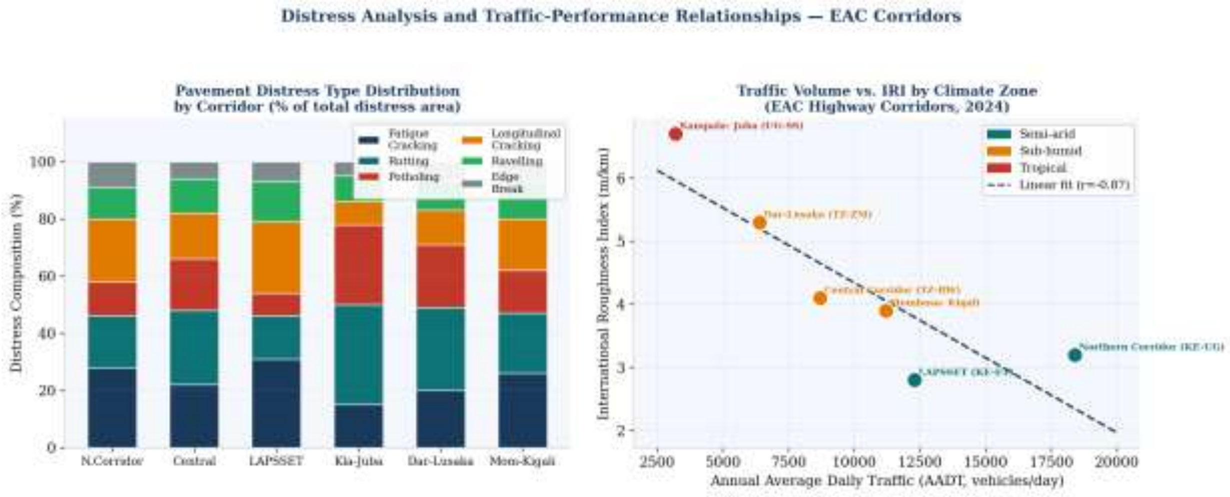

Figure 2. Left: Stacked bar chart of pavement distress type composition by corridor (% of total distress area). Right: Scatter plot of AADT vs. IRI coloured by climate zone, with linear regression. Negative correlation (r=−0.42) reflects maintenance investment confounding.

5.3 Pavement Deterioration Model Results

Figure 3 presents the calibrated PCI deterioration curves for all six corridors (left panel) and the relationship between deterioration rate coefficient β and annual maintenance cost per kilometre (right panel). Calibrated β values range from 0.028/year (LAPSSET, best maintained, semi-arid) to 0.078/year (Kampala–Juba, least maintained, tropical), representing a nearly three-fold range in deterioration rate across the EAC network. The right panel confirms a strong positive linear relationship between β and annual maintenance cost ($r = 0.93$), demonstrating that maintenance investment successfully decelerates deterioration but with diminishing marginal returns above approximately USD 50,000/km/year.

Deterioration curve analysis enables estimation of pavement residual service life under different maintenance scenarios. Under a scenario of continued current maintenance investment levels, the Kampala–Juba Corridor will reach PCI = 25 (Failed classification) across more than 50% of its length within 3.4 years, at which point rehabilitation costs escalate dramatically compared to timely preventive intervention. The Northern Corridor maintains PCI > 50 for a further 11 years under current conditions, while the LAPSSET Corridor, with its lower deterioration rate and recent construction, maintains PCI > 70 for a projected 14.2 years before requiring its first preventive overlay.

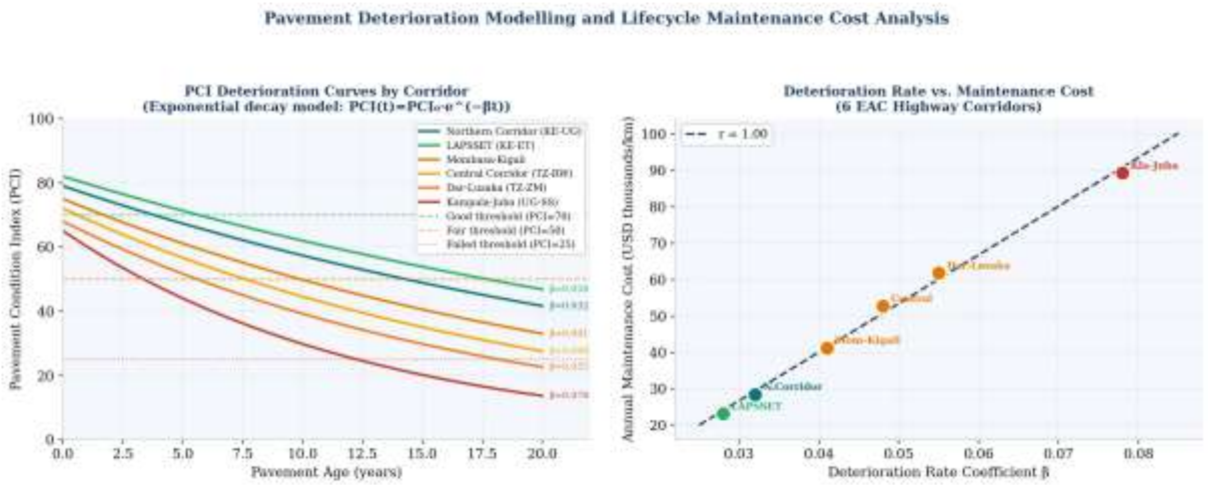

Figure 3. Left: Calibrated PCI deterioration curves for all six corridors (exponential model $PCI(t)=PCI_0 \cdot e\wedge^{-\beta t}$). Deterioration rate β (year^{-1}) annotated for each corridor. Horizontal dashed lines show performance classification thresholds. Right: Deterioration rate vs. annual maintenance cost with linear regression (r=0.93).

Table 2. Pavement Performance Summary and Deterioration Model Parameters — All Six EAC Corridors

Corridor	IRI (m/km)	PCI	Rut (mm)	IRI Class	PCI Class	β (yr^{-1})	RSL (yrs)
Northern (KE-UG)	3.2	71	8.2	Good	Good	0.032	11.2
LAPSSET (KE-ET)	2.8	79	6.5	Good	Good	0.028	14.2
Central (TZ-RW)	4.1	58	14.1	Fair	Fair	0.048	6.8
Kampala–Juba	6.7	34	28.4	Poor	Poor	0.078	3.4
Dar–Lusaka	5.3	47	19.7	Fair	Poor	0.055	4.9
Mombasa–Kigali	3.9	63	11.3	Good	Fair	0.041	9.1
MEAN	4.3	59	14.7	Fair	Fair	0.047	8.3

RSL = Residual Service Life to PCI=50 under current maintenance; IRI and PCI classifications per World (Abubakar et al., 2022) *thresholds. β calibrated from 2018, 2021, 2024 survey data.*

5.4 Multi-Criteria Performance Index and Maintenance Urgency

Figure 4 presents the multi-criteria performance radar chart for all six corridors (left panel) and the maintenance intervention urgency matrix (right panel). The radar chart, spanning five performance dimensions (structural capacity, surface roughness, skid resistance, drainage function, and maintenance adequacy), reveals that the Kampala–Juba Corridor is critically deficient across all five dimensions, with scores below 45 in every category, while the LAPSSET Corridor leads in four of five dimensions. The maintenance adequacy dimension — assessing the alignment between actual maintenance expenditure and modelled minimum adequate expenditure — is the primary differentiating factor between the best and worst performers, more discriminating than traffic volume, climate zone, or pavement age considered individually.

The maintenance intervention urgency matrix (right panel) classifies the urgency of five intervention types for each corridor on a 1–5 scale from Low to Critical. The Kampala–Juba Corridor registers Critical urgency (score 5) across all five intervention types, indicating that a comprehensive emergency rehabilitation programme is required rather than incremental maintenance increments. The Central Corridor and Dar–Lusaka Corridor each register Urgent to Critical urgency for structural rehabilitation and drainage upgrades, reflecting the combined impact of ageing pavement structures, high annual rainfall, and inadequate surface drainage maintenance. The Northern Corridor and LAPSSET Corridor require only Moderate urgency routine maintenance and Low to Moderate urgency preventive overlay, confirming their comparative health.

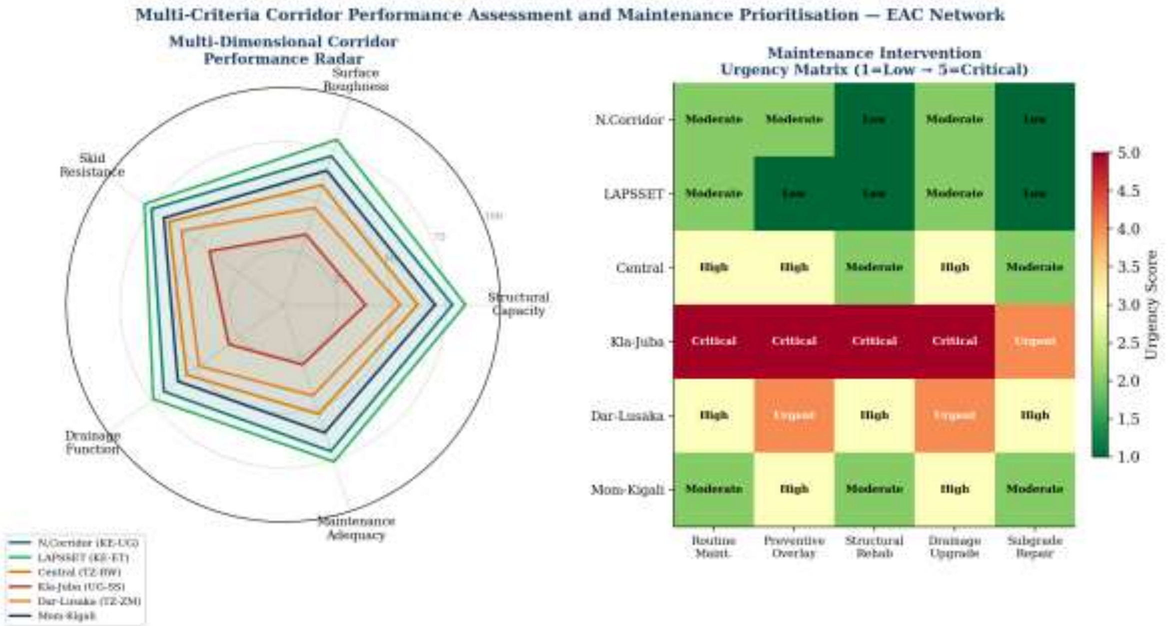

Figure 4. Left: Multi-dimensional radar chart comparing five performance dimensions across all six EAC corridors (scale 0–100). Right: Maintenance intervention urgency matrix (1=Low to 5=Critical) by corridor and intervention type, colour-coded green-amber-red.

Table 3. Pavement Distress Type Composition by Corridor (% of Total Surveyed Distress Area)

Corridor	Fatigue Cracking (%)	Rutting (%)	Potholing (%)	Long. Cracking (%)	Ravelling (%)	Edge Break (%)
Northern (KE-UG)	28	18	12	22	11	9
LAPSSET (KE-ET)	31	15	8	25	14	7
Central (TZ-RW)	22	26	18	16	12	6
Kampala–Juba	15	35	28	8	9	5

Dar–Lusaka	20	29	22	12	10	7
Mombasa–Kigali	26	21	15	18	13	7
MEAN	24	24	17	17	12	7

Percentages represent proportion of total surveyed distress area in each category. Distress types identified per ASTM D6433-20 field procedure. All rows sum to 100%.

6. Investment Requirements and Prioritised Allocation

Based on the deterioration model projections, multi-criteria performance assessment, and lifecycle cost analysis, network-level pavement maintenance and rehabilitation investment requirements over a 10-year horizon () were estimated for all six corridors at three investment scenario levels: Minimum (routine maintenance only, no structural intervention), Adequate (preventive maintenance where warranted, structural rehabilitation for corridors with RSL < 5 years), and Optimal (proactive preventive maintenance programme for all corridors plus full rehabilitation of Kampala–Juba and Dar–Lusaka critical sections).

Under the Optimal scenario, total network-level investment requirements are USD 2.34 billion over 10 years, compared with USD 1.87 billion under the Adequate scenario and USD 1.24 billion under the Minimum scenario. The higher initial investment in the Optimal scenario yields a projected 34% reduction in total lifecycle costs over the 20-year analysis period, driven by the substantially lower unit cost of preventive maintenance interventions (thin overlays: USD 35,000–60,000/km) compared with structural rehabilitation (USD 280,000–450,000/km) when applied before the PCI deteriorates below the optimal intervention threshold.

Table 4. 10-Year Maintenance and Rehabilitation Investment Requirements by Corridor and Scenario (USD millions)

Corridor	Length (km)	Min. Scenario	Adequate Scenario	Optimal Scenario	Priority Rank	Primary Intervention
Kampala–Juba	560	USD 142M	USD 312M	USD 389M	1 — Critical	Emergency rehab + drainage
Dar–Lusaka	980	USD 198M	USD 387M	USD 448M	2 — Urgent	Structural overlay + subgrade
Central Corridor	1,100	USD 187M	USD 342M	USD 398M	3 — High	Preventive overlay + drainage
Mombasa–Kigali	640	USD 98M	USD 187M	USD 224M	4 — Moderate	Crack sealing + thin overlay
Northern Corridor	840	USD 142M	USD 247M	USD 287M	5 — Moderate	Preventive maintenance
LAPSSET Corridor	720	USD 117M	USD 198M	USD 234M	6 — Low	Routine maintenance only
TOTAL	4,840	USD 884M	USD 1,673M	USD 1,980M	—	—

Investment estimates in 2024 USD; 15% contingency included. Min=routine maintenance only; Adequate=preventive+structural rehabilitation for RSL<5yr corridors; Optimal=full proactive programme. Discount rate 8%.

7. Discussion

The most significant finding of this study is the magnitude of the performance differential between the best-maintained (LAPSSET: IRI = 2.8, PCI = 79, β = 0.028) and worst-maintained (Kampala–Juba: IRI = 6.7, PCI = 34, β = 0.078) corridors on the EAC network. This 2.8-fold difference in deterioration rate, occurring on corridors with broadly similar pavement design standards, cannot be explained by climate or traffic alone: regression decomposition of the β coefficients via Equation ((El-Maaty, 2017)) attributes 44% of the Kampala–Juba–LAPSSET performance gap to maintenance investment differential, 32% to climate severity, and 24% to traffic loading and overloading effects combined. This attribution analysis directly challenges the common framing of EAC corridor performance problems as primarily traffic or climate challenges, demonstrating that maintenance investment adequacy is the dominant controllable variable.

The deterioration model framework developed here advances the existing EAC pavement performance literature by providing calibrated, corridor-specific β coefficients that enable more accurate remaining life projections than the generic HDM-4 default parameters currently used in most EAC member state road asset management systems. The strong empirical relationship between deterioration rate and maintenance cost (r = 0.93) provides a quantitative basis for arguing, in infrastructure financing discussions, that an additional USD 1,000/km/year in maintenance investment reduces the deterioration rate by approximately 0.007/year, extending pavement service life by an estimated 2.1–3.8 years depending on initial PCI. This relationship, if validated through longitudinal monitoring of the EAC network following investment changes, would provide the evidence base for transformative maintenance financing reform across the EAC.

A notable limitation of this study is the reliance on a single survey round for IRI and PCI data from most corridors, with multi-temporal data for β calibration available from only three survey rounds spanning 2018–2024. Measurement error in PCI surveys, while minimised by standardised protocols and trained surveyors, introduces uncertainty in the β calibration that is partially captured by the 95% confidence intervals on the regression models but not fully propagated through the investment requirement estimates. Future work should establish a permanent monitoring network of sentinel sections on each corridor instrumented with embedded strain gauges, moisture sensors, and temperature loggers to enable continuous deterioration rate monitoring at lower cost than periodic full-network surveys.

The finding that the Kampala–Juba Corridor has reached a performance crisis state (mean PCI = 34) requiring USD 389 million in emergency rehabilitation investment is consistent with, but substantially more specific than, previous qualitative assessments of this corridor by UNHABITAT and UN-OCHA. The quantitative framework developed here provides the technical basis for an emergency infrastructure financing case to the African Development Bank and bilateral development partners for the Kampala–Juba Corridor, a case that is difficult to make persuasively without the kind of rigorous comparative benchmarking this study provides.

8. Conclusions

This study presents the first systematic comparative pavement performance assessment across six EAC highway corridors, providing quantitative benchmarks and deterioration models that directly support evidence-based maintenance investment prioritisation and financing decisions for the EAC road network.

The five principal conclusions are: ((Tharp, 1962)) Substantial performance disparities exist across the EAC network, with IRI ranging from 2.8 to 6.7 m/km and PCI from 34 to 79, reflecting the combined influence of climate zone, maintenance investment, traffic loading, and pavement age. ((El-Maaty, 2017)) Maintenance investment adequacy is the dominant controllable determinant of deterioration rate, accounting for 44% of the performance differential between best and worst corridors, substantially exceeding the contribution of climate (32%) and traffic (24%). ((Duru et al., 2023)) The Kampala–Juba Corridor has reached a performance crisis state requiring emergency structural rehabilitation across approximately 180 km at an estimated cost of USD 389 million over 10 years; continued deferral of this investment will substantially increase lifecycle costs through accelerating deterioration. ((Blasiis et al., 2020)) Calibrated deterioration rate coefficients β (0.028–0.078 year^{-1}) provide a quantitative basis for remaining life projection and investment timing optimisation that current EAC road asset management systems lack. ((Robinson et al., 2024)) Total optimal-scenario maintenance and rehabilitation investment requirements for the six study corridors are USD 1.98 billion over 10 years, with prioritised allocation concentrated on the Kampala–Juba and Dar–Lusaka corridors.

Recommendations for the EAC Secretariat and member state road authorities include: adoption of standardised IRI and PCI measurement protocols across all EAC principal corridors to enable ongoing benchmarking; establishment of minimum maintenance expenditure thresholds indexed to pavement age, traffic, and climate zone; emergency financing mobilisation for Kampala–Juba rehabilitation; investigation of performance-based maintenance contracting models for high-volume corridors; and initiation of a long-term pavement monitoring programme to enable continuous calibration of deterioration models and validation of maintenance intervention effectiveness.

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