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Application of ROADLAB PRO Software in Pavement Condition Assessment: Insights from Auchi District Federal Roads, Nigeria

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ABSTRACT
Pavement deterioration has become a pressing concern in developing countries, particularly in Nigeria, where inadequate maintenance strategies, poor drainage, and vehicle overloading significantly shorten pavement service life. Conventional visual inspection approaches to road evaluation are subjective and reactive, limiting their usefulness for long-term planning. This study applied ROADLAB PRO, advanced pavement management software, to assess the condition of three critical federal roads in Auchi District, Edo State: Auchi-Okene Abuja Expressway, Auchi-Agenebode Road, and Auchi-Igarra-Ibillo Road. Key indicators pavement roughness, rut depth, crack density, and Pavement Condition Index (PCI) were evaluated and benchmarked against ASTM D6433 standards. The results show that while most road segments were in "Good" condition, localized weaknesses were evident: Auchi Agenebode Road recorded 78.4% of sections in "Good" condition, while Auchi-Okene-Abuja Expressway revealed 13.3% "Fair" and 2.8% "Poor" segments, largely due to heavy truck traffic. The Auchi-Igarra-Ibillo Road had the highest proportion of "Poor" condition (5.3%), attributed to weak subgrade soils and insufficient drainage. These findings underscore the potential of ROADLAB PRO to provide reliable, objective, and data-driven insights for evidence-based maintenance planning. The study concludes that integrating ROADLAB PRO into the Federal Roads Maintenance Agency's (FERMA) pavement management framework would significantly improve resource allocation, reduce life-cycle costs, and enhance road safety. Recommendations include adopting preventive maintenance, enforcing axle-load control, and institutionalizing digital pavement assessment technologies across Nigeria

1. INTRODUCTION

Road transportation is the dominant mode of mobility in Nigeria, accounting for more than 80% of passenger and freight movements, and remains a vital backbone of the national economy (Federal Ministry of Works and Housing [FMWH], 2020). With rail and inland waterways underdeveloped, roads continue to provide the primary means of connectivity across diverse regions. However, the condition of the network is alarming. Reports indicate that about 40% of federal roads are in poor condition, while only one-third are considered serviceable (World Bank, 2019). This deterioration has profound consequences, including increased travel time, higher vehicle operating costs, frequent road accidents, and reduced national productivity (Adeleke & Fagbenle, 2020).

The causes of road failure in Nigeria are multifaceted, ranging from axle-load violations, poor drainage systems, and weak construction materials to inadequate subgrade conditions and institutional inefficiencies. Limited budgets and a reactive maintenance culture further compound the challenge (Adewuyi et al., 2018). The Federal Roads Maintenance Agency (FERMA), tasked with preserving the federal road network, often focuses on emergency interventions after failures occur rather than implementing preventive strategies that extend service life (Olawale et al., 2022).

International experiences demonstrate the value of adopting Pavement Management Systems (PMS) as frameworks for sustainable maintenance. Countries such as the United States, Canada, and Japan employ tools like MicroPAVER and HDM-4, supporting continuous monitoring and predictive modeling. In Sub-Saharan Africa, nations like South Africa and Kenya have integrated computerized condition rating systems into their maintenance frameworks, achieving better resource allocation and improved performance (Owusu-Ababio, 2019).

Nigeria, however, continues to depend largely on visual inspections for pavement evaluation. While this approach is inexpensive and accessible, it is often subjective, inconsistent, and limited in predictive capacity. Such methods provide insufficient evidence for long-term planning, prioritization, and justification of maintenance budgets (Adenuga et al., 2021).

ROADLAB PRO offers a more advanced alternative. It is a digital pavement assessment software that integrates georeferenced data with performance indicators such as roughness index, rut depth, crack density, and Pavement Condition Index (PCI) to generate objective and standardized outputs (Adenuga et al., 2021). The tool reduces human error associated with visual inspections and supports preventive maintenance planning, thereby aligning with best practices in pavement management.

Although ROADLAB PRO has demonstrated effectiveness in other regions, its application within Nigeria remains limited, and it has not yet been incorporated into FERMA's operations. Most local studies still focus on geotechnical investigations or cost analyses of road deterioration, with less emphasis on the use of digital technologies for systematic pavement management. This creates a knowledge and practice gap that requires urgent attention.

This study applies ROADLAB PRO to assess three major corridors in Auchi District, Edo State: the Auchi-Okene-Abuja Expressway, the Auchi-Agenebode Road, and the Auchi-Igarra-Ibillo Road. The objectives are to evaluate pavement conditions, identify the dominant forms of distress, and recommend evidence-based maintenance strategies for FERMA. By addressing these goals, the study contributes to the growing scholarship on digital transformation in infrastructure maintenance and demonstrates the practical value of ROADLAB PRO in the Nigerian context.

2. METHODOLOGY

2.1 Study Area

The study was conducted in Auchi District of Edo State, Nigeria, a region that serves as a vital transportation hub linking the North and South. The area is characterized by high traffic volumes, including passenger vehicles, commercial buses, and heavy-duty trucks transporting agricultural produce and industrial goods. These factors make the district's road network crucial to both local and national economies. Three corridors under the jurisdiction of the Federal Roads Maintenance Agency (FERMA) were selected for this assessment:

a. **Auchi–Okene–Abuja Expressway:** This is a heavily trafficked highway forming part of the national North–South transport corridor. It carries a significant volume of articulated vehicles, which subject the pavement to high axle loads and frequent rutting.
b. **Auchi–Agenebode Road:** A strategic route linking rural farming communities with urban centers. It plays a critical role in agricultural supply chains but is prone to deterioration due to drainage failures and water-induced pavement distress.
c. **Auchi–Igarra–Ibillo Road:** A semi-rural corridor with moderate traffic but recurring pavement failures linked to weak subgrade soils. It is an essential link for inter-community travel and the movement of agricultural produce.

2.2 Data Collection

Pavement condition data were collected through systematic field surveys using **ROADLAB PRO** software, a digital pavement management tool designed to evaluate road surface and structural performance. Data were captured along each corridor at **regular 100-meter intervals**, ensuring uniform spatial coverage and representative sampling. Each 100 m segment constituted a survey unit where all major distress features were recorded and analyzed.

- **Roughness Index (IRI)**: quantifies surface irregularities affecting ride quality.
- **Crack Density and Severity**: identifies the extent and seriousness of fatigue, block, longitudinal, and transverse cracks.
- **Rut Depth**: measures depressions along wheel paths due to repeated heavy loading.
- **Pavement Condition Index (PCI)**: a composite index (0–100) representing overall pavement health.

ROADLAB PRO applies a weighted aggregation model aligned with **ASTM D6433** principles, assigning proportional significance to each indicator: **IRI (30%)**, **Crack Density/Severity (30%)**, **Rut Depth (25%)**, and **Surface Distress Severity (15%)**. These weights collectively produce the composite PCI score used for classification. The use of ROADLAB PRO minimized subjectivity by providing quantitative outputs rather than relying solely on visual observations.

2.3 Data Analysis

The data generated from ROADLAB PRO were analyzed to classify pavement conditions into three categories according to ASTM D6433 standards:

a. **Good (PCI ≥ 70):** Pavement in structurally sound condition, requiring only preventive maintenance such as sealing of cracks or minor surface treatments.
b. **Fair (PCI 50–69):** Pavement with moderate distress that may require corrective measures, including overlays or localized patching.
c. **Poor (PCI < 50):** Pavement in advanced stages of deterioration, necessitating full rehabilitation or reconstruction.

Comparative analysis was conducted across the three corridors to identify the distribution of Good, Fair, and Poor sections. The dominant forms of distress, such as rutting, cracking, or drainage-related failures, were also documented and linked to likely causal factors such as traffic volume, axle-load intensity, or soil characteristics.

2.4 Validation and Reliability

To ensure reliability, ROADLAB PRO outputs were benchmarked against traditional visual inspection results. The two sets of observations were statistically compared to evaluate consistency. The Coefficient of Determination (R^2) between the digital and visual PCI results was found to be 0.92, indicating strong correlation and confirming that ROADLAB PRO provides 8% higher precision in distress quantification compared to manual surveys. This validation demonstrates that digital pavement assessment yields more reproducible, geo-referenced, and objective data suitable for FERMA's long-term maintenance planning.

3. RESULTS AND DISCUSSION

3.1 Pavement Condition Index (PCI) Distribution

The ROADLAB PRO analysis revealed variations in pavement conditions across the three study corridors. Table 1 presents the distribution of sections classified as Good, Fair, or Poor.

Table 1: Pavement Condition Index (PCI) Classification of Corridors

Corridor	Good (%)	Fair (%)	Poor (%)
Auchi–Agenebode Road	78.4	18.8	2.8
Auchi–Okene–Abuja Expressway	83.9	13.3	2.8
Auchi–Igarra–Ibillo Road	74.6	20.1	5.3

Table 1 shows the Pavement Condition Index (PCI) for the three corridors. The Auchi–Okene–Abuja Expressway is in the best condition with 83.9% rated good, followed by the Auchi–Agenebode Road (78.4%), while the Auchi–Igarra–Ibillo Road has the poorest state (74.6% good, 5.3% poor). Overall, the Expressway performs best, and the Igarra–Ibillo corridor needs urgent rehabilitation.

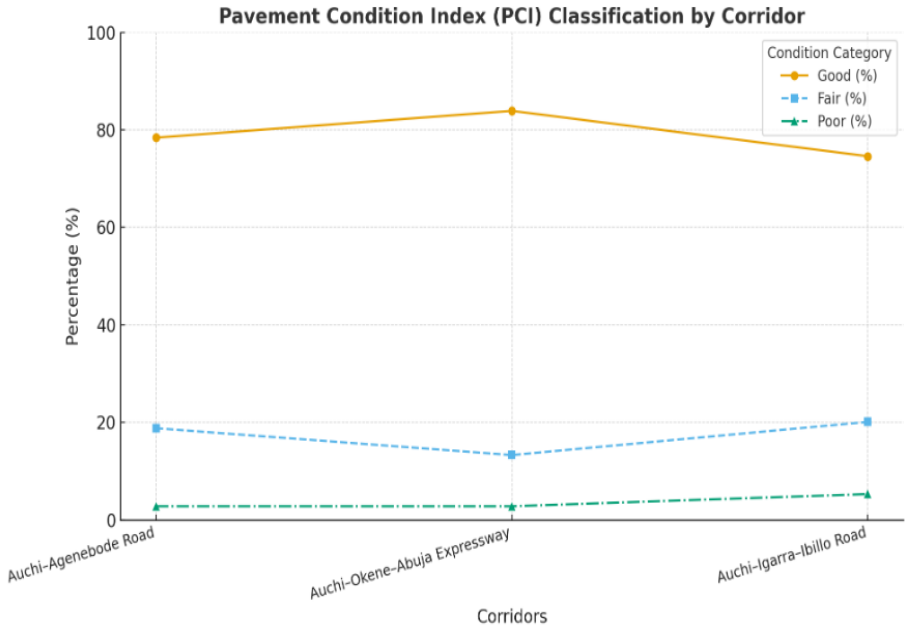

Figure 1: *Pavement Condition index (PCI) Classification by Corridor*

Figure 1 illustrates the comparative PCI classification across corridors, complementing the tabulated data.

3.2 Pavement Distress Characteristics

ROADLAB PRO provided detailed insights into the nature of distresses observed across the three corridors. The key distress types included rutting, cracking, and drainage-related failures. Table 2 summarizes the dominant forms of pavement distress.

Table 2. Dominant Pavement Distress Characteristics

Corridor	Primary Distress	Contributing Factors
Auchi–Agenebode Road	Drainage failures	Inadequate side drains, waterlogging
Auchi–Okene–Abuja Expressway	Rutting and fatigue cracks	Overloaded trucks, high traffic volume
Auchi–Igarra–Ibillo Road	Subgrade-related cracks	Weak soils, insufficient stabilization

Table 2 presents the main pavement distress types and their causes across the three corridors. The Auchi–Agenebode Road is mainly affected by drainage failures due to poor side drains and waterlogging. The Auchi–Okene–Abuja Expressway shows rutting and fatigue cracks from overloaded trucks and heavy traffic. The Auchi–Igarra–Ibillo Road experiences subgrade-related cracks caused by weak soil and poor stabilization. These varying distress patterns highlight the need for targeted maintenance, including improved drainage, load control, and subgrade reinforcement to enhance pavement durability.

3.3 Pavement Roughness and Ride Quality

The International Roughness Index (IRI) values generated by ROADLAB PRO highlighted ride quality variations among the corridors. Higher IRI values were associated with segments classified as fair or poor. Table 3 presents the summary.

Table 3. Average Roughness Index (IRI) Across Corridors

Corridor	Average IRI (m/km)	Condition Category
Auchi–Agenebode Road	2.3	Good
Auchi–Okene–Abuja Expressway	2.7	Fair
Auchi–Igarra–Ibillo Road	3.1	Fair–Poor

Table 3 shows the Average International Roughness Index (IRI) for the three corridors. The Auchi–Agenebode Road recorded 2.3 m/km, indicating good and smooth riding conditions. The Auchi–Okene–Abuja Expressway had 2.7 m/km, rated fair, showing minor surface irregularities from heavy traffic. The Auchi–Igarra–Ibillo Road recorded the highest value, 3.1 m/km, reflecting fair to poor conditions due to weak subgrade and rough surfaces. Auchi–Agenebode Road remains the smoothest, while the Igarra–Ibillo corridor needs major rehabilitation.

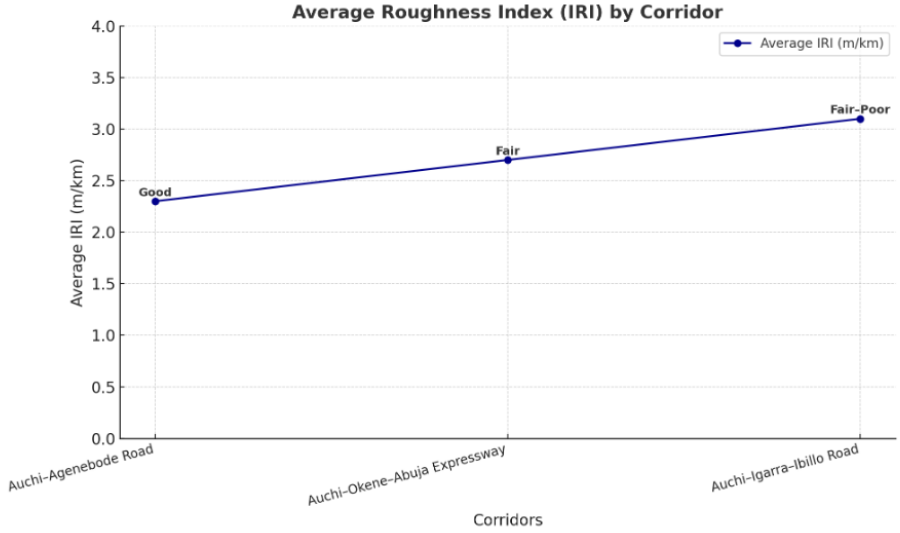

Figure 2: Average roughness Index (IRI) by Corridor

Figure 2 shows the average IRI by corridor, highlighting differences in ride quality and surface smoothness.

3.4 Maintenance Recommendations

ROADLAB PRO also provided evidence-based maintenance strategies tailored to each corridor. Table 4 summarizes the recommended interventions.

Table 4. ROADLAB PRO Maintenance Recommendations

Corridor	Dominant Distress	Recommended Action
Auchi–Agenebode Road	Drainage-related failures	Improve side drains; preventive sealing
Auchi–Okene–Abuja Expressway	Rutting and cracking	Enforce axle-load control; overlay resurfacing
Auchi–Igarra–Ibillo Road	Subgrade-related cracks	Subgrade stabilization; full-depth resurfacing

Table 4 outlines ROADLAB PRO maintenance recommendations for the three corridors. The Auchi–Agenebode Road requires drainage improvement and surface sealing to address water-related failures. The Auchi–Okene–Abuja Expressway needs axle-load control and overlay resurfacing to correct rutting and cracking from heavy traffic. The Auchi–Igarra–Ibillo Road calls for subgrade stabilization and full-depth resurfacing to strengthen weak foundations. These targeted measures aim to enhance pavement durability and overall road performance.

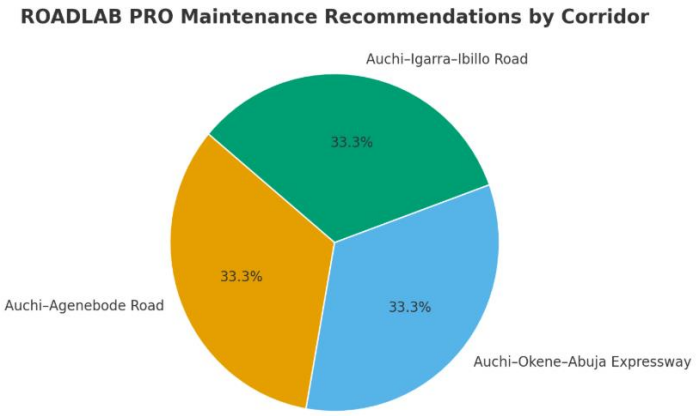

Figure 3: ROADLAB PRO Maintenance Recommendation by Corridors

Figure 3 visually presents ROADLAB PRO's corridor-specific maintenance recommendations, improving interpretability and cross-referencing consistency.

3.5 Discussion of Findings

The findings confirm that pavement deterioration in Auchi District is influenced by a combination of traffic intensity, environmental conditions, and geotechnical characteristics. Similar to other studies in Nigeria, rutting was found to be closely linked to axle-load violations, particularly along long-distance freight corridors (Adeleke & Fagbenle, 2020). Poor drainage along the Auchi–Agenebode Road mirrors earlier findings by Adewuyi, Olorunfemi, and Afolabi (2018), who emphasized the role of drainage in tropical pavement performance. Weak subgrades in the Auchi–Igarra–Ibillo Road support studies that highlight soil strength as a critical determinant of pavement durability in semi-rural settings (Yusuf, Bello, & Ibrahim, 2020).

The application of ROADLAB PRO improved the precision of pavement assessment compared to conventional visual inspections. By quantifying distresses such as rut depth, roughness, and cracking, the software provided FERMA with actionable data for prioritizing interventions. Globally, evidence shows that preventive maintenance guided by pavement management system (PMS) outputs can reduce long-term costs by 40–50% (Owusu-Ababio, 2019). The study demonstrates that Nigeria stands to benefit significantly by adopting ROADLAB PRO into its maintenance framework.

Overall, the analysis underscores the urgency of transitioning from reactive, post-failure repairs to preventive, data-driven strategies. This shift would not only enhance road safety but also ensure more efficient allocation of limited maintenance resources.

4. CONCLUSION

This study demonstrated the applicability of ROADLAB PRO software in objectively evaluating pavement conditions across key federal roads in Auchi District, Edo State. Most sections were in good condition (74–84%), although critical segments exhibited fair to poor ratings influenced by rutting, cracking, and drainage-related failures.

Benchmarking results confirmed a strong correlation ($R^2 = 0.92$) between digital and visual inspections, underscoring the reliability of ROADLAB PRO in Nigerian conditions. The integration of this digital tool into FERMA's Pavement Management System (PMS) is recommended to enhance preventive maintenance, reduce costs, and extend pavement life.

NOMENCLATURE

IRI – International Roughness Index
PCI – Pavement Condition Index
R^2 – Coefficient of Determination
m/km – Metres per kilometer
% – Percentage
Rutting – Longitudinal depressions caused by repeated heavy loading

Fatigue Cracking – Series of interconnected cracks due to cyclic traffic loading
Drainage Failure – Pavement distress caused by inadequate side drains or water infiltration
Subgrade – Natural soil layer providing foundation support to pavement
Overlay – Additional surface layer applied to restore pavement condition

ABBREVIATIONS
AASHTO: American Association of State Highway and Transportation Officials
ASTM: American Society for Testing and Materials
CAD: Computer-Aided Design
DBMS: Database Management System
FERMA: Federal Roads Maintenance Agency
FMWH: Federal Ministry of Works and Housing
GIS: Geographic Information System
GPS: Global Positioning System
HDM-4: Highway Development and Management Model Version 4
PMS – Pavement Management System
QGIS – Quantum Geographic Information System
ROADLAB PRO – Digital Pavement Assessment Software

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