

Assessment of Pavement Surface Distresses and Development of Pavement Condition Index from School of Remedial Studies Junction - Joseph Sarwuan Tarka University Gate Road, Makurdi, Benue State

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Abstract

This study assesses the pavement condition of the School of Remedial Studies (SRS) Junction–Joseph Sarwuan Tarka University Makurdi (JOSTUM) gate Road using the Pavement Condition Index (PCI) methodology (ASTM D6433-07). The objective was to classify pavement sections based on PCI scores and recommend maintenance strategies. Surface distresses such as cracking, potholes, rutting, and shoving were surveyed and categorized by severity. The results reveal varying PCI scores across 66 road segments. Segments rated as Good (PCI > 80) were found between 4000–4100 m and 6500–6572 m, requiring minimal maintenance. Poor and Very Poor conditions (PCI 25–54) dominated the roadway, including critical segments such as 0–100 m (PCI 45) and 200–300 m (PCI 25). Failed segments (PCI < 10) were identified from 5300–5900 m, necessitating urgent reconstruction. Overall, the findings highlight significant structural distress due to high traffic loads and inadequate maintenance. Timely and total rehabilitation of flexible road pavement on the SRS-JOSTUM road is recommended since over 72% of the road network is at deplorable state; the prompt rehabilitation of the worse segments (having the least % for fair and above conditions) should be given priority. Also, the patching of potholes at this stage of deterioration is essential to prevent further damages and thereby reducing cost of rehabilitation in the future.

Keywords: Flexible road pavement, Pavement Condition Index (PCI), maintenance strategies, surface distress, pavement rehabilitation, deduct values.

Introduction

The road network in every society serves as an important foundation for the effective functioning of transportation and this contributes in delivering a wide range of economic and social benefits. The importance of road increases as the population of the society increases, especially in the absence of other means of transport such as railways and waterways which is often the case in developing countries of which Nigeria is one (Ugwu and Mbadike, 2023). Road transportation is the pivot of transport system in most developing countries on the Africa continent. The use of road transport requires efficient or workable and sustainable management system and policies for sustainable development to cater for a large human population and corresponding travel demand over time. Consequently, like many other assets, road infrastructures deteriorate over time hence call for proper planning for efficient management system (Olowosulu et al., 2020 and Chen and Lin, 2020). Therefore, continuous road pavement monitoring and performance assessment are essential aspects of transport infrastructural development and management policies to curtail congested traffic flow, air and noise pollution, travel delay, accidents (Adeke et al., 2019).

A flexible paved road is an elastic structure whose elements are made of different unbound layers of soil materials that exhibit nonlinear behaviour under the influence of damaging factors (Ayed, 2016). Its topmost layer is usually a thin Hot-Mixed Asphalt (HMA) known as the wearing course (other types include hot-laid, cold mix and cold laid) which is laid on the base layer. Both the base and its supporting sub-base layers consist of suitable soils with designed properties while the topmost layer called the surface or wearing course is usually an asphaltic concrete designed to carry traffic load directly and resist skidding (Garber and Hoel, 2009). The major disadvantages of flexible road pavement are its relatively short life cycle of 20

years and rapid deterioration and consequent failure with time due to significant impact of climate (temperature and precipitation), traffic load, material properties, pavement structure, design standard (Adeke et al., 2019). The severity of road distresses such as pot holes, cracks, shoveling goes a long way in affecting the values of these indices (Dong and Huang, 2020, Setyawan et al., 2015 and ASTM D6433, 2007). Understanding the current condition of this pavement and developing appropriate maintenance strategies is crucial for prolonging its service life and ensuring safety for all users (Federal Ministry of Works and Housing, 2022 and Smith and Jones, 2021).

Basically, the assessment of pavement deterioration and consequent damage employs different engineering techniques which require field data generated onsite or obtained from pavement management agencies or from experienced engineers working on pavement distresses (Huang, 2004). The performance of pavements is usually measured using one of the following indices: Pavement Condition Index (PCI), Pavement Condition Rating (PCR), International Roughness Index (IRI), Present Serviceability Index (PSI), Present Serviceability Rating (PSR), Ride Number (RN) and Profile Index (PI) (Mazari and Rodriguez, 2006, Moriasi et al., 2020, Lee and You, 2021). Pavement condition indices (PCIs) are numerical values used to quantify the overall condition of a pavement based on observed distresses. The most widely used Pavement Condition Index ranges from 0 to 100, with higher values indicating better pavement conditions (Adeke et al., 2019). According to the Transportation Research Board (2019), the PCI is an effective tool for prioritizing maintenance and rehabilitation efforts.

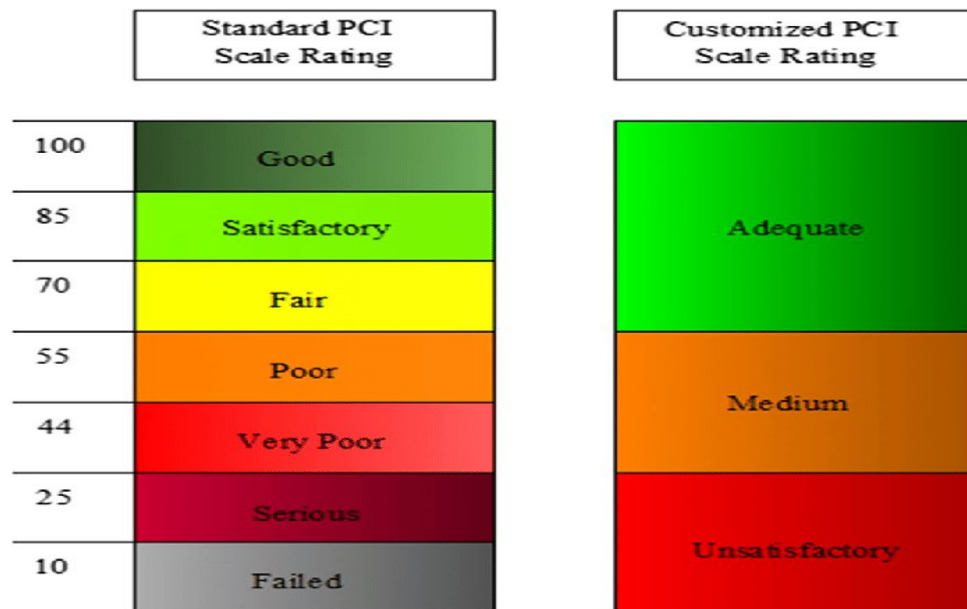


Figure 1: Standard PCI rating scale (Source: ASTM, 2007)

The Pavement Condition Index (PCI) is a numerical rating system developed to assess the surface condition of pavements, ranging from 0 (failed) to 100 (excellent). This score provides an objective basis for evaluating pavement performance and planning maintenance actions. ASTM D6433 (2007) outlines a systematic procedure for calculating the PCI based on observed distresses, factoring in both their type and severity. This calculation involves determining deduct values for each distress and applying a correction to these values to obtain the PCI score. Each section of the pavement is visually surveyed to identify and record different types of surface distresses. Observations include distress types such as longitudinal cracking, transverse cracking, alligator/fatigue cracking, and potholes, each categorized by severity levels: low, medium, or high. The extent of each distress is also quantified (in square meters or linear meters) as specified in ASTM D6433-07. The deduct value represents the impact of a particular distress on pavement

performance, as defined by ASTM D6433-07. For each observed distress, a deduct value is assigned based on the distress type, extent, and severity. Higher-severity distresses have higher Deduct values, which decrease the PCI more significantly.

Deduct values are extracted from standardized tables in ASTM D6433-07. After obtaining deducts values for each distress in a pavement section, the next step is to calculate the Total Deduct Value (TDV). The TDV is the sum of all deducts values for the distresses within that section, providing an initial measure of the extent of pavement deterioration. Since different distresses interact and contribute differently to the overall pavement condition, ASTM D6433-07 uses a Corrected Deduct Value (CDV) to avoid over-penalizing sections with multiple distresses. The CDV accounts for the number and severity of distresses by capping the deduct values. For instance, if the TDV is under 40, no correction is needed, and the CDV equals the TDV. If the TDV is higher, ASTM D6433-07 provides a correction curve to adjust the TDV to a lower CDV. The CDV is determined by ranking the highest deduct values in descending order and applying ASTM's correction formula or lookup tables (ASTM, 2007). The PCI score for each section is calculated by subtracting the CDV from 100. This subtraction ensures that more distresses and higher severities result in a lower PCI score, indicating poorer pavement condition.

Though, more observation shows the road corridor of SRS – JOSTUM is in a deplorable state, based on the level of deterioration of the flexible road pavements, this statement could not be justified using facts and figures since there is no technical and sectional assessment of the road sections which would have given an exact description of the pavement condition for optimum decision making and resource allocation. This study therefore aims at evaluating the present pavement condition of SRS Junction – JOSTUM gate road corridor using the ASTM D6433-07 standard manual. Objectives of the study include; to carryout site inspection of road pavement distresses along the route based on defined road segments, to estimate PCI values of road segments using the ASTM D6433-07 standards and to propose effective maintenance strategy framework for flexible road pavements.

Materials and Methods

Description of the Study Area

The study focused on the School of Remedial Studies (SRS) Junction-Joseph Sarwuan Tarka University Makurdi, gate (Makurdi-Gbajimba) Road, a critical link in the region's transportation network. This road is essential for daily commuting, agricultural activities, and accessing educational facilities. The route begins at the SRS Junction, traversing through urban and semi-urban areas, and terminates at the Joseph Sarwuan Tarka University Makurdi Gate. The geographical coordinates of the road extend from approximately 7.7333° N latitude to 8.5333° E longitude. Total length of paved roadway measures about 6.572 km to serve people living and using to work. The road network is made of flexible pavements only. This road has undergone series of rehabilitations and maintenance in the past. The layout of road segment is as shown in Figure 2.

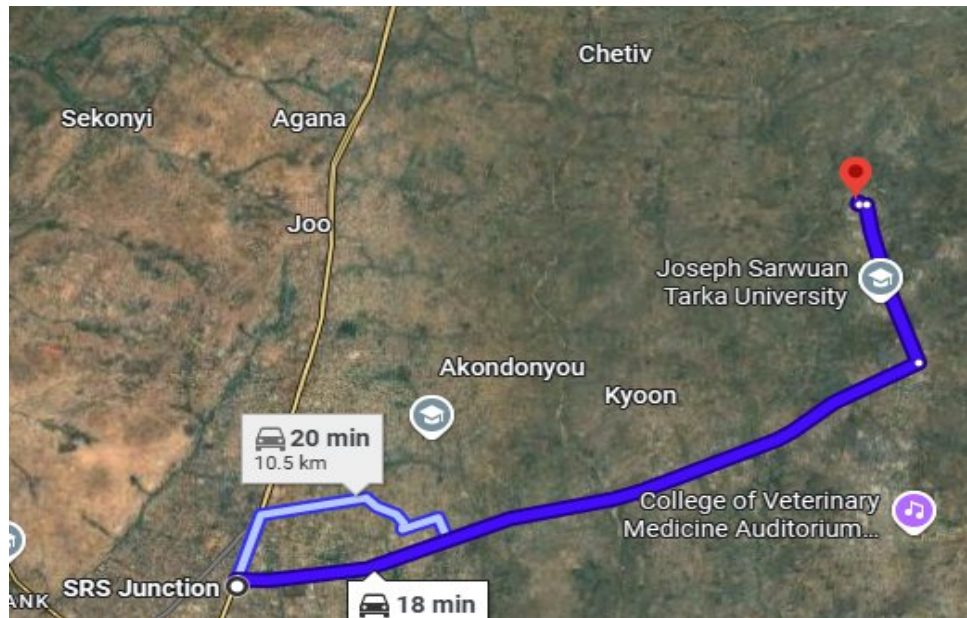


Figure 2: A map showing the study area, SRS Junction –JOSTUM gate (Makurdi-Gbajimba) road
(Source: Google Map, 2026)

Data Collection and Analysis

Data collection for this study was carried out using two primary methods, field surveys and visual inspection. The fieldwork involved visual inspection of pavement conditions of the road. The road corridor was divided into segments for examination and the geometry of defects in terms of widths and lengths per road segment were measured. The paved road corridors were subdivided into segments each measuring 100 meters long with varied widths for easy assessment. The quantity and severity of surface distresses were measured using linear measuring instruments such as measuring tape and metal rule in line with specifications of the ASTM D6433 (2007) manual. For each section, the types of distresses present were identified and recorded. This included noting the specific characteristics of each distress, such as crack width and length, pothole depth, and rut depth. This was carried out during off office periods (mostly Sundays) to enable enumerators work conveniently and under a secured condition without safety threats since a limited number of vehicles travelled along the road corridors on Sundays. Results were recorded and the analysis of collected data involved estimation of the density of distress and deduct values per road segment from charts in accordance with procedure in ASTM D6433 manual.

PCI Calculation

The PCI calculation transforms distress survey data into a single numerical condition rating through a four-step process:

Step 1: Compute Distress Density: For each distress entry (type + severity combination), divide the measured quantity by the total sample unit area. The density, $d = 100 \times \frac{A_{distress}}{A_{sample}}$ expressed as a percentage.

Step 2: Determine Deduct Values (DV): For each distress density-severity pair, read the corresponding deduct value from the ASTM D6433 (2007) deduct value curves. The curves are derived from empirical pavement deterioration modeling and reflect the relative contribution of each distress to overall pavement degradation.

Step 3: Determine Maximum Corrected Deduct Value (CDV): Sort all individual deduct values from highest to lowest. Determine m , the maximum number of allowable deducts, using the formula $m = 1 +$

$\left(\frac{9}{98} \times (100 - \text{HDV})\right)$ where HDV is the highest individual deduct value. Step 4: Compute PCI: $\text{PCI} = 100 - \text{CDV}_{\max}$ where $\text{CDV}_{\max}$ is the maximum CDV obtained across all iterations.

Results and Discussion

The distresses observed on the SRS Junction-JOSTUM gate roadway are as shown in the Table 1

Table 1: Distresses observed

Distress Type	Severity Level	Location (Segment)	Extent	Notes
Longitudinal Cracking	Low	Km 1-5	50 m	Temperature changes
	Medium	Km 3-5	75 m	Temperature changes
	High	Km 2-4	100 m	High-severity areas require sealing
Transverse Cracking	Low	Km 1-4	20 m	Temperature changes
	Medium	Km 2-4	60 m	Frequent at temperature changes
	High	Km 2-4.5	75 m	High-severity areas require sealing
Edge Cracking	High	Km 1&3-5	100 m	Patching and shoulder stabilization
	Medium	Km 1-4.5	50 m	Shoulder stabilization recommended
	Low	Km 1-5	25 m	Shoulder stabilization recommended
Alligator/Fatigue Cracking	High	Km 1-2, 3-4.5	120 m ²	Immediate repair recommended
	Medium	Km 2-5	50 m ²	Cracks sealing recommended
Block Cracking	Low	Km 1-5	20 m ²	Cracks sealing
	High	Km 2-5	120 m ²	Instant Sealing recommended
Potholes	Medium	Km 1-2&4	25 m ²	Cracks sealing
	High	Km 1-4.5	10 m ²	Immediate repair recommended
Delamination	Medium	Km 2-5	4 m ²	Pothole patching
	Low	Km 3-5	2 m ²	Pothole patching
	High	Km 1-4	100 m ²	Immediate repair recommended
Shoving	Medium	Km 3-4.7	25 m ²	Early repair recommended
	Low	Km 1-4	15 m ²	Asphalt laying
	High	Km 3-4.2	80 m ²	Immediate repair recommended
	Medium	Km 3-4	25 m ²	Asphalt recommended overlay
	Low	Km 2-3	10 m ²	Asphalt recommended overlay
Shoulder Drop off	High	Km 1-5	100 m	shoulder stabilization recommended
	Medium	Km 2-4	80 m	shoulder stabilization recommended
Rutting	Medium	Km 4-5	80 m ²	Asphalt recommended overlay
	Low	Km 1-4	20 m ²	Asphalt recommended overlay
Raveling	High	Km 2-3	160 m ²	Asphalt recommended overlay
	Medium	Km 4	50 m ²	Asphalt recommended overlay

	Low	Km 1&5	10 m ²	Asphalt recommended	overlay
Slippage cracking	Medium	Km 2&4	30 m ²	Cracks recommended	sealing
	Low	Km 1&3	15 m ²	Cracks recommended	sealing
Upheaval	Low	Km 2-5	100 m ²	Asphalt recommended	overlay

The road connecting SRS – JOSTUM was sub-divided into segments identified by codes using a constant length of 100 meters for all segments. The distribution of PCI ratings for various road segments along routes are as shown in Table 2.

Table 2: Distribution of PCI and Ratings of various road segments along routes

Location (m) Starts From JOSTUM gate	ID Code of Segments	Total Deduct values	Corrected Deduct Values	PCI	Segments Rating
0 – 100	JST-SRS-01	94.4	55.0	45	Poor
100 – 200	JST-SRS-02	91.7	63.0	37	Very Poor
200 – 300	JST-SRS-03	139.3	75.0	25	Serious
300 – 400	JST-SRS-04	128.1	64.0	36	Very Poor
400 – 500	JST-SRS-05	119.6	61.0	39	Very Poor
500 – 600	JST-SRS-06	103.9	68.0	32	Very Poor
600 – 700	JST-SRS-07	90.4	60.0	40	Poor
700 – 800	JST-SRS-08	105.4	59.0	41	Poor
800 – 900	JST-SRS-09	93.7	61.0	39	Very Poor
900 – 1000	JST-SRS-10	74.2	56.0	44	Poor
1000 – 1100	JST-SRS-11	30.1	30.0	70	Fair
1100 – 1200	JST-SRS-12	79.7	50.0	50	Poor
1200 – 1300	JST-SRS-13	52.0	37.0	63	Fair
1300 – 1400	JST-SRS-14	55.9	42.0	58	Fair
1400 – 1500	JST-SRS-15	49.3	41.0	59	Fair
1500 – 1600	JST-SRS-16	53.7	37.0	63	Fair
1600 – 1700	JST-SRS-17	35.1	35.0	65	Fair
1700 – 1800	JST-SRS-18	78.7	48.0	52	Poor
1800 – 1900	JST-SRS-19	57.5	32.0	68	Fair
1900 – 2000	JST-SRS-20	66.0	53.0	47	Poor
2000 – 2100	JST-SRS-21	195.6	87.0	13	Serious
2100 – 2200	JST-SRS-22	154.3	71.0	29	Very Poor
2200 – 2300	JST-SRS-23	71.5	43.0	57	Fair
2300 – 2400	JST-SRS-24	67.1	49.0	51	Poor
2400 – 2500	JST-SRS-25	55.6	41.0	59	Fair
2500 – 2600	JST-SRS-26	75.9	38.0	62	Fair
2600 – 2700	JST-SRS-27	63.2	49.0	51	Poor
2700 – 2800	JST-SRS-28	46.0	33.0	67	Fair
2800 – 2900	JST-SRS-29	38.1	38.0	62	Fair
2900 – 3000	JST-SRS-30	70.5	46.0	54	Poor
3000 – 3100	JST-SRS-31	66.3	41.0	59	Fair
3100 – 3200	JST-SRS-32	52.0	40.0	60	Fair

3200 – 3300	JST-SRS-33	51.3	35.0	65	Fair
3300 – 3400	JST-SRS-34	39.1	39.0	61	Fair
3400 – 3500	JST-SRS-35	48.6	35.0	65	Fair
3500 – 3600	JST-SRS-36	91.2	59.0	41	Poor
3600 – 3700	JST-SRS-37	84.0	52.0	48	Poor
3700 – 3800	JST-SRS-38	66.0	44.0	56	Fair
3800 – 3900	JST-SRS-39	59.1	37.0	63	Fair
3900 – 4000	JST-SRS-40	28.3	28.0	72	Satisfactory
4000 – 4100	JST-SRS-41	18.4	18.0	82	Good
4100 – 4200	JST-SRS-42	43.0	33.0	67	Fair
4200 – 4300	JST-SRS-43	93.4	59.0	41	Poor
4300 – 4400	JST-SRS-44	102.1	64.0	36	Very Poor
4400 – 4500	JST-SRS-45	91.0	60.0	40	Poor
4500 – 4600	JST-SRS-46	53.9	43.0	57	Fair
4600 – 4700	JST-SRS-47	99.3	67.0	33	Very Poor
4700 – 4800	JST-SRS-48	91.2	63.0	37	Very Poor
4800 – 4900	JST-SRS-49	172.6	85.0	15	Serious
4900 – 5000	JST-SRS-50	142.1	67.0	33	Very Poor
5000 – 5100	JST-SRS-51	165.0	78.0	22	Serious
5100 – 5200	JST-SRS-52	129.6	75.0	25	Serious
5200 – 5300	JST-SRS-53	112.3	86.0	14	Serious
5300 – 5400	JST-SRS-54	123.0	96.0	4	Failed
5400 – 5500	JST-SRS-55	173.6	95.0	5	Failed
5500 – 5600	JST-SRS-56	193.1	97.0	3	Failed
5600 – 5700	JST-SRS-57	160.3	93.0	7	Failed
5700 – 5800	JST-SRS-58	115.1	90.0	10	Failed
5800 – 5900	JST-SRS-59	185.0	98.0	2	Failed
5900 – 6000	JST-SRS-60	195.0	88.0	12	Serious
6000 – 6100	JST-SRS-61	190.5	83.0	17	Serious
6100 – 6200	JST-SRS-62	195.1	82.0	18	Serious
6200 – 6300	JST-SRS-63	80.8	55.0	45	Poor
6300 – 6400	JST-SRS-64	75.1	43.0	57	Fair
6400 – 6500	JST-SRS-65	58.8	31.0	69	Fair
6500 – 6572	JST-SRS-66	28.3	7.0	93	Good

Table 3: Descriptive Statistics of PCI Values

Statistic Parameters	PCI Values
Mean	44.74
Standard Deviation	20.82
Sample Size	66
Range	91
Variance	433.57
Coefficient of Variation (%)	46.54
Standard Error	2.58
Skewness	-0.32
Excess Kurtosis	-0.51
Minimum	2
Maximum	93
<i>Percentiles:</i>	
10th Percentile	13.4
25th Percentile	33
50th Percentile (Median)	47

75th Percentile	61
90th Percentile	67

The statistical analysis of the Pavement Condition Index (PCI) data provided in Table 3 gives insights into the overall condition and distribution of the pavement across the studied segments.

Statistical insights showed an average PCI value for the entire road network as approximately 45, and a high standard deviation (20.82), which shows that the average rating of pavement condition of road network is poor based on the PCI scale. In summary, the percentage frequency distribution of PCI and ratings for various routes of the entire road network are as shown in Table 4. This provides a clear view of the pavement condition for each kilometer segment along the road, highlighting areas that need immediate attention based on higher percentages in the Failed and Serious categories. The percentages of road segments for fair to good pavement condition to include; 0-1 km, 1-2, 2-3, 3-4, 4-5, 5-6, 6-6.572km with 20.0%, 50.0, 60.0, 80.0, 30.0, 0% and 28.6% respectively. Road segments along the 0-1km segment had majorly very poor or fair pavement conditions, while those along the 1-2km were very poor, serious and failed the rating. The rating of road segments on the 2-3km segment fell between fair, poor and good. Road segments along the 3-4km routes are described or rated as being fair and satisfactory. The 4-5km segment is rated as being poor, satisfactory and good. The combined 5-6km and 6-6.572km segments are mostly rated as being at the completely damaged, poor, serious, fair and good states. In spite of their significant bad condition, there are some good and satisfactory segments along the 2-3km. 4-5km and 6-6.572km segments.

Table 4: Percentage Distribution of PCI and Ratings for various Road Segments

Rating of Pavement Condition	0–1 km (%)	1–2 km (%)	2–3 km (%)	3–4 km (%)	4–5 km (%)	5–6 km (%)	6–6.572 km (%)
Failed	0.0	0.0	0.0	0.0	0.0	60.0	14.3
Serious	10.0	10.0	0.0	0.0	10.0	30.0	42.9
Very Poor	40.0	20.0	10.0	0.0	20.0	30.0	0.0
Poor	30.0	20.0	30.0	30.0	30.0	20.0	0.0
Fair	20.0	50.0	50.0	70.0	10.0	0.0	14.3
Satisfactory	0.0	0.0	0.0	10.0	10.0	0.0	0.0
Good	0.0	0.0	10.0	0.0	10.0	0.0	14.3

Table 5: PCI rating of entire Road Network from SRS Junction to JOSTUM gate

Rating of Pavement Condition	Frequency of Segments	Rating (No. of Segments)	% Frequency Distribution of PCI of Road Segments
Failed	9		13.8%
Serious	11		16.9%
Very Poor	13		20.0%
Poor	14		21.5%
Fair	11		16.9%
Satisfactory	4		5.45%
Good	4		5.45%
Total	66		100%

Table 5 provides an overview of the overall pavement condition distribution, highlighting the proportion of segments that fall under each condition rating as failed, serious, very poor and fair conditions in accordance with PCI scale with percentage composition ranging from 20 – 25%. 13.8% failed completely, only 5.45% of the road segment is both rated as being satisfactory and good conditions respectively. The analysis of the collected data presents a comprehensive evaluation of pavement conditions on the SRS junction-JOSTUM gate road. Utilizing the Pavement Condition Index (PCI) methodology, results showed that over 72% of the road network on the SRS-JOSTUM road is rated between poor and failed state. Only 11% of road segments on the road segment are classified as being satisfactory and under good condition.

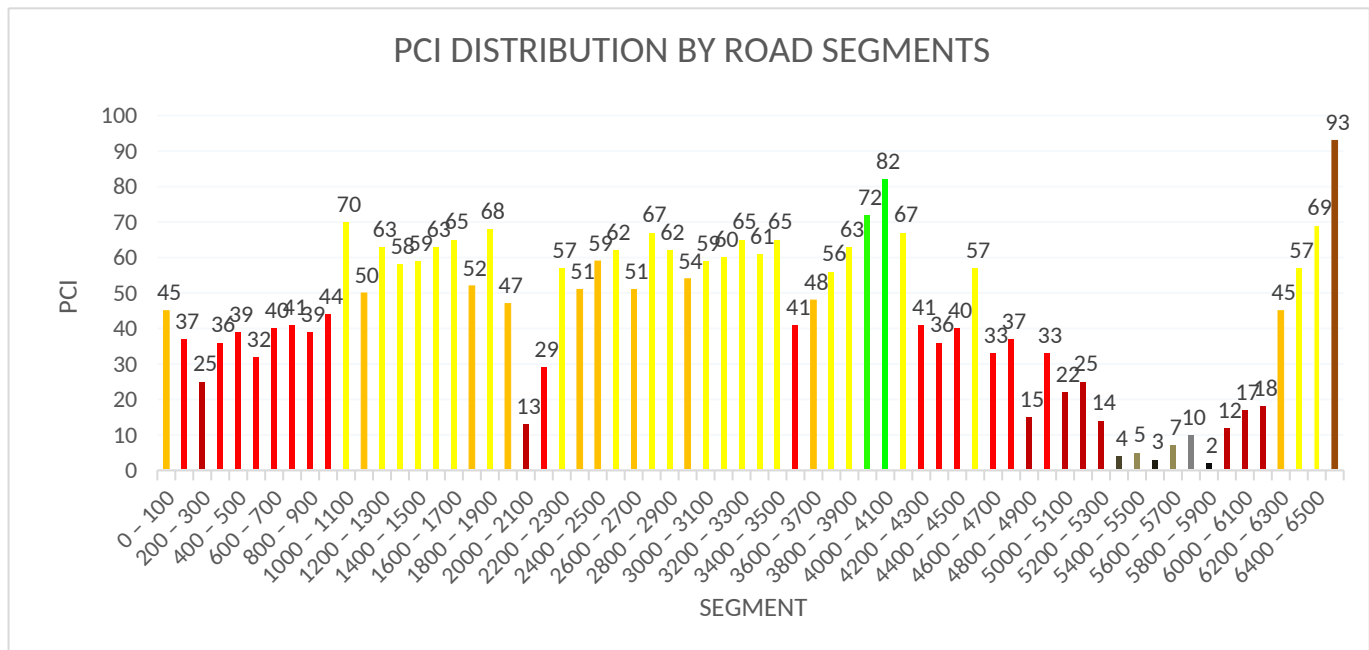


Figure 3: Combined Distribution of PCI along SRS Junction – JOSTUM gate road, Makurdi

Figure 3 revealed that significant number of road segment have PCI values below the fair status of 50. Over 50% of the road segments are in critical condition (Failed, Serious, or Very Poor), requiring urgent interventions such as sealing, patching, and overlays. However, with over 50% of segments scoring below the median PCI of 47, the findings underscore the need for a prioritized maintenance strategy to add severe distresses like alligator cracking, potholes, and rutting.

Conclusions

Based on assessment carried out by this study using the ASTM D6433 standards manual for assessing PCI of flexible road pavement, it can be concluded that;

Road pavement on the SRS Junction-JOSTUM gate road is generally rated as being in a poor or failed state at the rate of over 72%, with only 11% classified as being satisfactory and under good condition. A fraction of segments at different intervals were rated differently between fair to good conditions.

The 4-5km segment had relatively high percentage of fair to good road pavement condition with 5-6km segment having the worst pavement condition which makes the SRS Junction-JOSTUM gate road pavement requires extensive interventions, including full-depth repairs or complete reconstruction.

Without timely rehabilitation, the pavement will continue to deteriorate, potentially leading to increased maintenance costs.

Recommendations

The following recommendations can be made;

Total rehabilitation of road from SRS Junction-JOSTUM gate is required since over 72% of the road pavement is in bad state with only 11% good segments.

Annual assessment of road pavement condition of the road to ascertain the level of road pavement deterioration for purposes of budgetary planning and timely rehabilitation strategies in terms of prioritization, rehabilitation by cutting and patching of potholes at the present stage of road deterioration on the network to prevent further damages, hence reducing the cost of future rehabilitation and establishing

a Pavement Management System (PMS) that can facilitate systematic tracking of pavement conditions and provide a data-driven basis for maintenance planning.

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