Uniport Journal of Engineering and Scientific Research (UJESR)

Vol. 4, Issue 1, 2019, Page 75 - 83
ISSN: 2616-1192

(www.ujesr.org)

Pavement Condition Index Evaluation of Flexible Pavements at the Abuja Campus of University of Port Harcourt

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Abstract
The deterioration of road pavements can be qualitatively measured using the pavement condition index (PCI). The incessant complaints of Staff and Road users of the University of Port Harcourt about the state of flexible pavements in the institution necessitated this study. Thus, this study evaluated the status of the flexible pavements at the Abuja campus of University of Port Harcourt using PCI. The major link roads were categorised into eight (8) sections with each section divided into segments of 100m and their state evaluated using PCI as per relevant standards. From analysis of results obtained, the road pavement on Abuja campus was generally rated as being in a fair state with an average PCI value of 58%. Specifically, 20% of the pavements were rated satisfactory, 62% were rated between fair to satisfactory conditions and 18% were rated below the fair condition status. Although the road condition of sections considered in this study was rated fair, annual assessment of road pavement condition of the road network at Abuja campus was recommended to ascertain the level of road pavement deterioration and for purposes of budgetary planning and timely rehabilitation strategies in terms of road prioritization.

Keywords: *Flexible pavement, Pavement rehabilitation, Pavement Condition Index, University of Port Harcourt*

Received: 15th December, 2019 *Accepted: 30th December, 2019*

1. 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 area 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. The importance of highways in the development of any economy cannot be overemphasized. The existence of this very important infrastructure is naturally threatened by several deteriorating factors ranging from human to environmental factors (GFRN, 2014). Timely intervention in the rehabilitation of pavements has been proven to save about 50% of cost of rehabilitation, hence, the need for frequent monitoring of these pavements' conditions (Arabani et al., 2017).

Flexible pavement which is the commonest pavement type in developing countries such as Nigeria consists of several layers of granular nutrients covered with bituminous material. This may be due to its relatively cheap cost of initial construction (Taylor and Philip, 2015). The topmost layer of flexible pavement is usually a thin Hot Mix Asphalt known as the wearing course which is laid on the base layer. This wearing course is designed to carry traffic load directly and resist skidding (Garber and Hoel, 2009). The periodic deterioration and consequent failure of road pavements has become a serious cause for concern to road management agencies, hence, assessing the level of damage over time is essential for sustainable road asset management in terms of risk reduction and budgetary planning (Yin, 2007; Ziliute et al., 2016).

Assessment of pavement deterioration and consequent damage employs different engineering techniques which require field data generated on-site 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) (Yu, 2005; Mazari and Rodriguez, 2006). The severity of road distresses such as pot holes, cracks, shoveling, etc. go a long way in affecting the values of these indices (Setyawan et al., 2015; ASTM D6433, 2007).

According to Al- Neami et al. (2017), the PCI is one of the most widely used indices for road pavement performance assessment. The PCI is a numerical value established from a visual inspection and geometric measurement of surface distresses of pavements as per the relevant standards. The PCI provides a numerical value between 0 and 100, where 0 represents worst condition and 100 represents the best condition. It is a very simple and inexpensive method of evaluating pavement performance.

The incessant complaints about some sections of the roads in Abuja campus by road users prompted this study. These complaints could not be justified using facts as there was no assessment of these road sections for optimum decision making and resource allocation. This study was therefore aimed at evaluating the condition of flexible pavements at the University of Port Harcourt, Abuja campus using the PCI in accordance to ASTM D6433 (2007) and PAVER (1982).

2. Materials and methods

2.1 Research design

This research is geared towards evaluating the conditions of flexible pavements of major link roads in Abuja Campus of the University of Port Harcourt. The Pavement Condition Index (PCI) method of evaluation was adopted in the evaluation process. The flexible pavements were categorized into eight (8) sections. The study was carried out in every hundred (100) meters for each section. The PCI procedure as per ASTM D6433 (2007) and PAVER (1982) were used in this study to evaluate the road sections. During a PCI survey, visible signs of deterioration are recorded and analysed. The result obtained from the PCI studies were analysed and used in the rating of the Maintenance and Rehabilitation (M and R) needs of the road sections, rating of the rideability of road network and the overall PCI value of the flexible road network in the Abuja Campus of University of Port Harcourt.

2.2 Study area

The University of Port Harcourt has a total area of 461 hectares divided into Choba, Delta and Abuja campuses by three public roads with the Abuja Campus located at coordinates 4° 52' 30" and 4° 55' 00" N, 6° 54' 40" and 6° 55' 49"E. The major link roads to all administrative and academic points were considered. These link roads were grouped into eight (8) sections totalling a span of about 4.7km. These sections are indicated by the blue colour paths in Fig. 1 and their associated route lettering. Section 1 is from Delta Park gate to Ofrima intersection (DPGO) with a span of 1.69km. Section 2 is from Management Sciences start junction to Management Sciences junction (MSJM) in Alex Otti drive with a road span of 402.15m. Section 3 is from Management Sciences junction to Ebitimi Banigo junction (MSJE) with a road span of 556.33m. Section 4 is from Senate junction to Bottling Plant junction (SBPJ) with a span of 456.87m. Section 5 is from Bottling Plant junction to Nuclear Centre junction (BPJN) with a road span of 302.40m. Section 6 is from Nuclear Centre junction to Basic Road junction (NCBJ) with a road span of 368.98m. Section 7 is from Ofrima intersection to UPTH gate (OUPT) with a span of 628.13m and Section 8 is from ICTC junction to Clinical Road end (ICCR) with a road span of 315.69m. The lane width of the flexible pavements ranged from 3.50m to 3.65m.

2.3 Field data collection

Each of the sections was segmented into hundred (100) meters for a proper Pavement Condition Evaluation analysis. All road defects/distresses were identified in these segmented areas before analysis of flexible pavements. Table 1 shows the asphalt pavement inspection sheet used during the field study. The field study was conducted during off peak hours, especially during close of work to reduce the disturbing effects of traffic.

2.4 Determination of pavement condition index (PCI)

In determining the PCI for this study, the following outlined steps according to ASTM D6433 (2007) and PAVER (1982) were adopted:

- Division of the road sections into segments
- Determination of the number of segments for each section and hence the total segments required for the study.
- Identification of the different distresses encountered in this study.

- Determination of the density and severity of distresses for each segment.
- Determination of deduct value and total deduct value for each section
- Determination of the corrected deduct value for each section
- Determination of the PCI for each section.

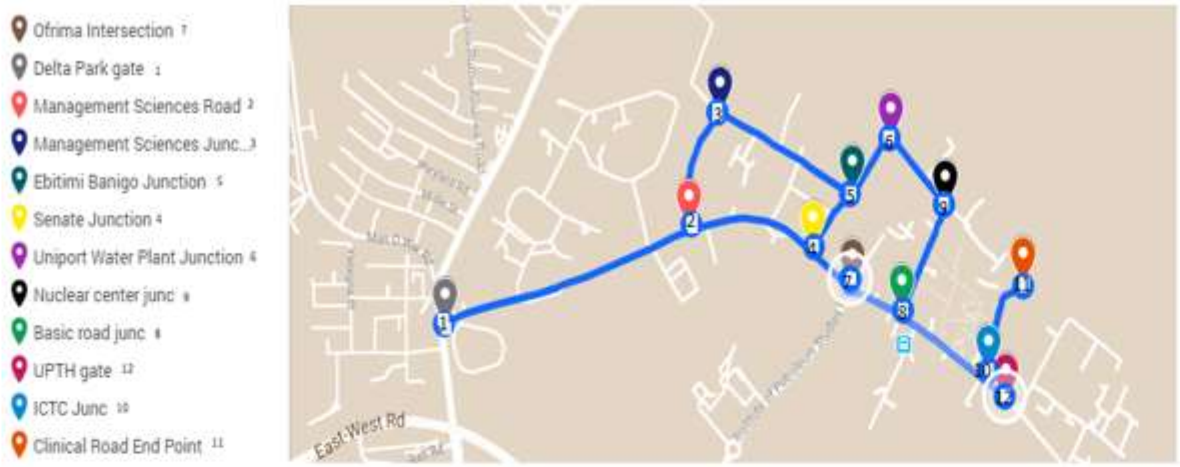

Fig. 1: Study area with associated legends

Table 1: Asphalt pavement inspection sheet

SECTION: ___________________ DATE: _______________________ SURVEYED BY:________________	SEGMENT: ________________ SEGMENT UNIT: ___________ AREA OF SEGMENT:________
Distress Types 1. Alligator Cracking 2. Bleeding 3. Block Cracking 4. Bumps and Sags 5. Corrugation 6. Depression 7. Edge Cracking 8. Jt. Reflection Cracking 9. Lane/ Shld. Drop off 10. Long. & Trans. Cracking 11. Patching & Util. Cut Patching 12. Polished Aggregates 13. Pot holes 14. Rail road Crossing 15. Rutting 16. Shoving 17. Slippage Cracking 18. Swell 19. Weathering & Ravelling	Road Sketch; 100 m B

EXISTING DISTRESS TYPE; QUANTITY & SEVERITY						
Type						
QUANTITY & SEVERITY						
TOTAL SEVERITY						
PCI CALCULATION FOR SEGMENT						

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE	
TOTAL DEDUCT VALUE				PCI = 100 – CDV
CORRECTED DEDUCT VALUE				

NB: All distresses are measured in square meters with exception of distresses 4, 7, 8, 9 and 10 which are measured in linear meter; distress 13 is measured in number of pot holes.

2.4.1 Division of road sections into segments

The eight road sections selected for this study were divided into different segments of hundred (100) meters. That is, the PCI evaluation was conducted for a span of hundred (100) meters per segment for every road section selected for the study. These segments were identified by a code name derived from the primary route or section name. The section names are: DPGO, MSJM, MSJE, SBPJ, BPJN, NCBJ, OUPT and ICCR.

2.4.2. Determination of required number of segments

The number of segments evaluated for each section was determined using Equation (1).

$$Ns = \frac{L_i}{L_s} \qquad (1)$$

where Ns = Number of segments for section i, L_i = Length of section i and L_s = Length of one segment = 100m.

With the aid of Equation (1), Table 2 showing the number of segments for each section and also the total number of segments for the study was developed.

Table 2: Segments for study

Section Designation	Span (m)	No. of Segments
DPGO	1690	17
MSJM	402.15	4
MSJE	556.33	6
SBPJ	456.87	5
BPJN	302.40	3
NCBJ	368.98	4
OUPT	628.13	7
ICCR	315.69	4
Total	4720.55	50

2.4.3. Determination of the density and severity of distresses

The severity of identified distresses for the different segments were rated qualitatively using the ratings of high, medium and low based on the visual inspection of the distresses. The determination of the density of distresses was based on the distress type under consideration. Density of the distresses measured in square meters (m^2) was calculated using Equation (2).

$$Density = \frac{distress\ amount\ in\ m^2}{Segment\ area\ in\ m^2} X\ 100 \qquad (2)$$

Density of the distresses measured in linear meter (m) was calculated using Equation (3).

$$Density = \frac{distress\ amount\ in\ Linear\ meter}{Segment\ area\ in\ m^2} X\ 100 \qquad (3)$$

Density of the distresses measured by the number of pot holes was calculated using Equation (4).

$$Density = \frac{Number\ of\ pot\ holes}{Segment\ area\ in\ m^2} X\ 100 \qquad (4)$$

2.4.4. Determination of deduct value and total deduct value

The deduct value for every identified distress in every segment was determined from deduct value curves of the distress type (PAVER 1982; ASTM D6433 2007) with the aid of the calculated distress density. The Total Deduct Value (TDV) of distresses existing in a segment was determined by summation of all deduct values obtained for the different distresses existing in that segment. Mathematically, this is shown in Equation (5).

$$TDV = \sum_{i=1}^{n} D_i \qquad (5)$$

where D_i = Deduct value of distress I and n = number of identified distresses

2.4.5. Determination of the corrected deduct value (CDV)

The CDV of distresses in a segment was determined from the deduct value correction curves with the aid of the calculated TDV. When determining the CDV, if any individual deduct value is higher than the CDV, the CDV is set equal to the highest individual deduct value. Fig. 2 as obtained from the standard specifications (PAVER 1982; ASTM D6433 2007) was used in the determination of the CDV for the different segments considered in this study.

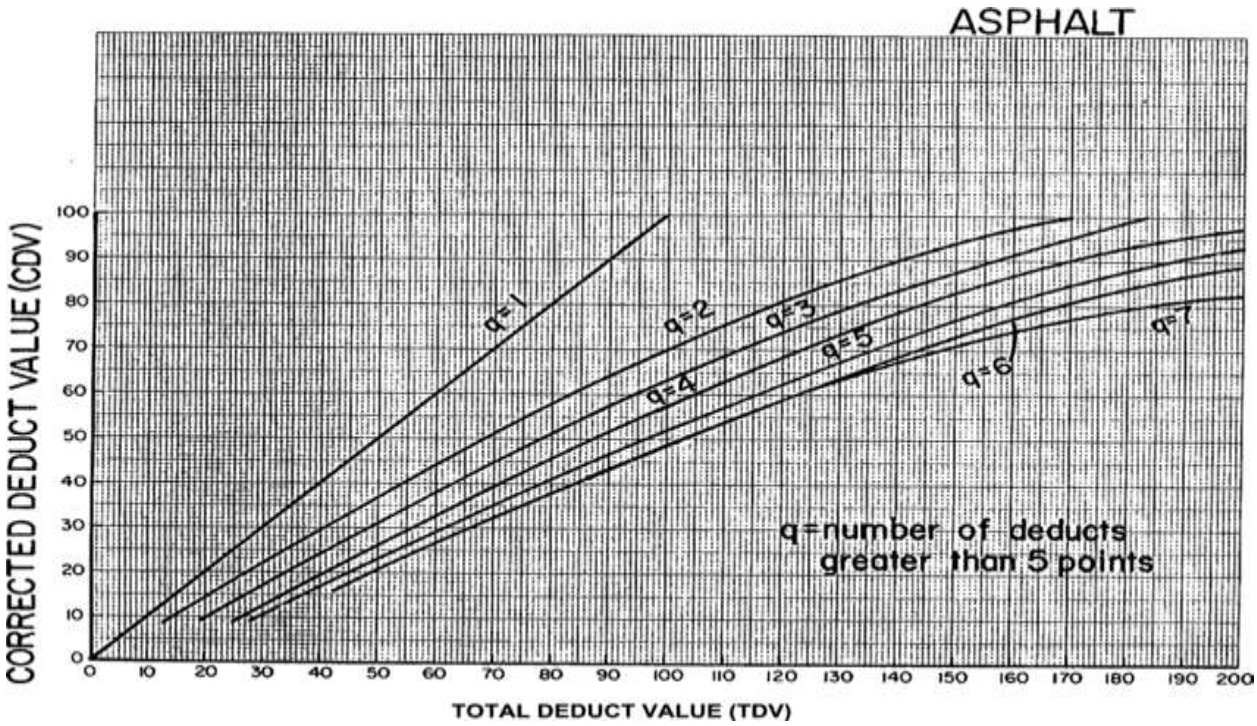

Fig. 2: Corrected deduct value curve (PAVER 1982; ASTM D6433 2007)

2.4.6. Determination and scaling of the pavement condition index (PCI)

The PCI for a segment was obtained from the CDV of the distresses identified in that segment using Equation (6).

$$PCI_i = 100 - (CDV)_i \quad (6)$$

where PCI_i = PCI value for segment i and $(CDV)_i$ = CDV for segment i. The PCI of an entire section of flexible pavement was then calculated as the average of the segmental PCI's obtained from Equation (6). This is represented mathematically by Equation (7).

$$PCI_s = \sum_{i=1}^{n} PCI_i \;/n \quad (7)$$

where PCI_s = PCI for section s, PCI_i = PCI for segment i of section s, and n = number of segments in section s. Table 3 shows the standard PCI scale established by ASTM D6433 (2007). The PCI assessment does not examine the structural status of the pavement but rather its physical appearance in terms of quantity and severity of distresses.

Table 3: PCI scale as per ASTM D6433 (2007)

Pavement Condition Rating	Pavement Condition Index
Good	86-100
Satisfactory	71-85
Fair	56-70
Poor	41-55
Very Poor	26-40
Serious	11-25
Failed	0-10

3. Results and discussion

3.1 PCI determination and ratings for section 1 (DPGO)

Using a constant length of 100 meters for all segments with varied number of lanes and widths, Table 4 shows various rating of pavement conditions for the road segments of Section 1 within the road network in Abuja campus. 41.2% segments of road Section 1 (DPGO) have PCI values of the fair condition status. 29.4% have PCI values of the poor status condition while 17.6% have PCI values belonging to the satisfactory condition status. 11.8% have PCI values of the very poor condition status. The average PCI value for this section is 57 indicating a fair condition status. This indicates that this road section though on the verge, has not yet lost its functional values of carrying traffic loads.

3.2 PCI determination and ratings for section 2 (MSJM)

Table 5 shows the various rating of pavement conditions for the road segments of Section 2 within the road network in Abuja campus. All the four segments in road Section 2 (MSJM) belong to the satisfactory condition class. The average of the PCI values of this road section is 77.5 belonging to the satisfactory road condition class. This implies that this road section satisfactorily performs its function of carrying traffic loads with little or no discomfort.

Table 4: PCI values and ratings of road segments for section 1

Section Designation	Code of Segments	Total Deduct values	Corrected Deduct Values	PCI	Rating
DPGO	1	55.8	34	66	Fair
	2	48.9	31	69	Fair
	3	59.4	36	64	Fair
	4	38.4	24	76	Satisfactory
	5	33.6	22	78	Satisfactory
	6	43.5	28	72	Satisfactory
	7	54.3	39	61	Fair
	8	69.4	57	43	Poor
	9	65.2	48	52	Poor
	10	49.5	39	61	Fair
	11	48.3	32	68	Fair
	12	57.6	43	57	Fair
	13	68.4	56	44	Poor
	14	72.1	64	36	Very Poor
	15	67.2	58	42	Poor
	16	75.3	67	33	Very Poor
	17	64.2	53	47	Poor

Table 5: PCI values and ratings of road segments for section 2

Section Designation	Code of Segments	Total Deduct values	Corrected Deduct Values	PCI	Rating
MSJE	1	54.6	46	54	Poor
	2	58.2	44	56	Fair
	3	62.4	55	45	Poor
	4	48.4	39	61	Fair
	5	53.5	47	53	Poor
	6	68.4	59	41	Poor

Table 6: PCI values and ratings of road segments for section 3

Section Designation	Code of Segments	Total Deduct values	Corrected Deduct Values	PCI	Rating
MSJE	1	54.6	46	54	Poor
	2	58.2	44	56	Fair
	3	62.4	55	45	Poor
	4	48.4	39	61	Fair
	5	53.5	47	53	Poor
	6	68.4	59	41	Poor

3.3 PCI determination and ratings for section 3 (MSJE)

Table 6 shows the various rating of pavement conditions for the road segments of Section 3 within the road network in Abuja campus. An average PCI value of 52 was obtained as the PCI value of this road section signifying a poor road condition status. This indicates that this road section requires minor rehabilitation works for it to serve its purpose of vehicular carriage.

3.4 PCI determination and ratings for section 4 (SBPJ)

Table 7 shows the various rating of pavement conditions for the road segments of Section 4 within the road network in Abuja campus. All the PCI values of segments in road Section 4 (SBPJ) are in fair road condition status except segment 1 whose PCI value indicates a poor road condition status. An average PCI value of 60 indicating a fair condition status was obtained for this road section. This is an indication that this road section is still able to perform its functions of carrying vehicular loads.

3.5 PCI determination and ratings for section 5 (BPJN)

Table 8 shows the various rating of pavement conditions for the road segments of Section 5 within the road network in Abuja campus. The average of the PCI values gave a value of 59 typifying a fair road condition status. This indicates that this road section though on the verge, has not yet lost its functional values of carrying traffic loads.

Table 7: PCI values and ratings of road segments for section 4

Section Designation	Code of Segments	Total Deduct values	Corrected Deduct Values	PCI	Rating
SBPJ	1	64.6	47	53	Poor
	2	59.7	45	55	Fair
	3	52.4	42	58	Fair
	4	44.5	38	62	Fair
	5	38.5	30	70	Fair

Table 8: PCI values and ratings of road segments for section 5

Section Designation	Code of Segments	Total Deduct values	Corrected Deduct Values	PCI	Rating
BPJN	1	44.3	38	62	Fair
	2	59.4	49	51	Poor
	3	42.4	37	63	Fair

Table 9: PCI values and ratings of road segments for section 6

Section Designation	Code of Segments	Total Deduct values	Corrected Deduct Values	PCI	Rating
NCBJ	1	55.4	46	54	Poor
	2	37.4	31	69	Fair
	3	64.6	53	47	Poor
	4	59.3	45	55	Fair

Table 10: PCI values and ratings of road segments for section 7

Section Designation	Code of Segments	Total Deduct values	Corrected Deduct Values	PCI	Rating
OUPT	1	22.4	18	82	Satisfactory
	2	21.3	19	81	Satisfactory
	3	35.7	28	72	Fair
	4	44.8	31	69	Fair
	5	33.9	25	75	Fair
	6	28.4	20	80	Satisfactory
	7	46.9	34	66	Fair

Table 11: PCI values and ratings of road segments for section 8

Section Designation	Code of Segments	Total Deduct values	Corrected Deduct Values	PCI	Rating
ICCR	1	82.5	59	41	Poor
	2	93.4	62	38	Very Poor
	3	102.6	93	7	Failed
	4	107.5	98	2	Failed

3.6 PCI determination and ratings for section 6 (NCBJ)

Table 9 shows the various rating of pavement conditions for the road segments of Section 6 within the road network in Abuja campus. Of the four road segments of Section 6 (NCBJ), 50% of the segments are in poor condition status while the other 50% are in fair condition state. An average PCI value of 56 means that the road section falls in the fair condition class. This is an indication that this section is in the threshold point (PCI = 56) and requires some minor rehabilitation works

3.7 PCI determination and ratings for section 7 (NCBJ)

Table 10 shows the various rating of pavement conditions for the road segments of Section 7 within the road network in Abuja campus. Three of the seven segments of road Section 7 (OUPT) showed satisfactory road conditions. The other four segments indicate fair road conditions. The average PCI value of 75 indicating a satisfactory road condition for Section 7 was obtained. This implies that this road section satisfactorily performs its function of carrying traffic loads with little or no discomfort.

3.8 PCI determination and ratings for section 8 (ICCR)

Table 11 shows the various rating of pavement conditions for the road segments of Section 8 within the road network in Abuja campus. All the segments in section 8 indicate undesirable road condition status. An average PCI value of 22 indicates that this road section requires serious rehabilitation works.

3.9 Statistical analysis of the PCI data

Table 12 presents the descriptive statistics of all the segments of the road network considered in this study. The descriptive statistics revealed that the mean of PCI values of road network in Abuja campus is 58.02 signifying a road condition of the fair status. The mode and median of the PCI values of 69 and 61 respectively was obtained in this study. This indicates that the most occurring PCI value is 69 with 61 being the PCI value located at the central of observation. The fair status of road condition in Abuja campus indicates that on a macroscopic scale, the functional values of traffic loads carriage of these pavements are still preserved.

Table 12: Descriptive statistics for data

Parameters	PCI Values
Mean	58.02
Standard Error	2.434864116
Median	61
Mode	69
Standard Deviation	17.21708928
Sample Variance	296.4281633
Kurtosis	2.016347086
Skewness	-1.114055041
Range	80
Minimum	2
Maximum	82
Sum	2901
Count	50
Largest (1)	82
Smallest (1)	2
Confidence Level (95.0%)	4.893042634

Table 13: Percentage distribution of PCI for various road sections

Rating of Pavement Condition	% Frequency Distribution of PCI of Road Sections							
	DPGO	MSJM	MSJE	SBPJ	BPJN	NCBJ	OUPT	ICCR
Failed	0	0	0	0	0	0	0	10.23
Serious	0	0	0	0	0	0	0	0
Very Poor	7.12	0	0	0	0	0	0	43.18
Poor	23.53	0	45.83	17.79	28.98	44.89	0	46.59
Fair	46.03	0	54.17	82.21	71.02	55.11	53.71	0
Satisfactory	23.32	100	0	0	0	0	46.29	0
Good	0	0	0	0	0	0	0	0

3.11 Rating the entire road network in Abuja campus

A significant number of road segments in Abuja campus are rated fair counting for about 42% of the entire road network as revealed by Table 14. 4% of the entire road network failed entirely, 6% are in a very poor condition, 28% are considered poor with only about 20% in satisfactory condition. This information indicates that majority (62%) of the road segments considered still satisfy the basic requirement of carrying traffic loads, 28% need minor rehabilitation and/or maintenance works with only 10% needing major rehabilitation or reconstruction.

Table 14: Rating of entire road network

Rating	Frequency of Occurrence	% Frequency
Failed	2	4
Serious	0	0
Very Poor	3	6
Poor	14	28
Fair	21	42
Satisfactory	10	20
Good	0	0

4. Conclusions

Based on the assessment carried out in this study using the ASTM D6433 standards manual for assessing PCI of flexible road pavement, it can be concluded that the road pavement in Abuja campus is generally rated as being in a fair state at rate of 58%, with about 20% classified as being in satisfactory condition. Majority of segments at different routes were rated differently between fair to satisfactory conditions, including; DPGO (69.35%), MSJM (100%), MSJE (54.17%), SBPJ (82.21%), BPJN (71.02%), NCBJ (55.11%), OUPT (100%) and ICCR (0%). Although the road condition of the sections considered in this study is rated fair, annual assessment of road pavement condition of the road network in Abuja campus is recommended to ascertain the level of road pavement deterioration and for purposes of budgetary planning and timely rehabilitation strategies in terms of prioritization.

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