Determination of Pavement Condition Index and Maintenance Cost Evaluation At The federal Polytechnic Nasarawa, Nigeria

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Abstract- ***The pavement condition index (PCI) is an easy, suitable and cheap way to evaluate the status of pavement surface distress in order to suggest the methods and time for maintenance and rehabilitation, as well as to serve as base for predicting the budget of same operations, with the ultimate goal of ensuring pavement sustainability. This research project assessed the quality of the surface condition of road branch ABCDEFG within the Federal Polytechnic Nasarawa flexible road network, and also determined the condition of drainages (and other road fittings) through a Road Inventory Survey earlier conducted. The inventory survey was done through physical inspection of the entire road branch while the Manual Pavement Condition Survey was carried out through measurement of the pavement distresses in ten sample units within section BCD of the road branch, and the data analyzed using normal PCI method. Blocked culverts, failed drainages and scarified shoulders were observed at some locations and the general pavement condition of the road section was very poor because PCI read 35%. It therefore means that there is an urgent need for a periodic maintenance such as overlay after patching. A Bill of Engineering Measurement and Evaluation (BEME) was therefore drafted for an immediate maintenance operation.***

Indexed Terms- ***Pavement Condition Index (PCI), Road Inventory Survey, Manual Pavement Condition Survey, Flexible Pavement, BEME.***

I. INTRODUCTION

Pavement deteriorations are starting immediately after inaugurating the road traffic, but these actions are not felt/noticed at this stage until after a reasonable period of time. Many studies describe the effective road deterioration to a limit in which between 20 and 60 % of it has gone bad, and if the trend continues the pavement fails completely within its lifespan of say 20 years. But with good pavement maintenance and rehabilitation culture in place, road status will significantly extend this lifespan in good shape (Babashamsiet, al; 2016). To accomplish this, a systematic procedure for scheduling M-and-R works to optimize the benefits to road users and minimize costs to the agency responsible for pavement management is recognized as a useful measure. Known as the Pavement Management System (PMS), such a system would allow administrators and engineers to allocate funds, personnel, resources, etc. most effectively (Hall et al. 1992). According to Adeke, P. et. al. (2019) ,the Pavement Condition Index (PCI) is normally determined biannually in order to evaluate changes that occur in the road network system. The road being surveyed has never had such an assessment in its entire history of about 18 years (from our Inventory Survey), hence the need for a Pavement Condition Survey now.

II. RESEARCH AIM

The aim of this research is to assess the quality of the surface condition of a road branch within the Federal Polytechnic Nasarawa, Nigerian flexible road network using the Pavement Condition Index (PCI) in order to suggest time and method of maintenance & rehabilitation, for pavement sustainability.

2.2 Research limitation

The Pavement Condition Index is a useful tool but it has its draw-backs. It is subjective. While most people would agree on which roads are rated as excellent and which ones are rated as poor, deciding

on whether a road is in fair condition or good condition is very difficult. Being too lenient may mean that important maintenance work is delayed. Being too strict may mean spending money on fixing a problem before it really needs to be done (Hall et al. 1992).

III. RESEARCH DESIGN

An Inventory Survey, which is usually targeted at providing relevant additional information such as presence and state of drainages, shoulders, kerbs and other road features goes a long way in facilitating such maintenance decisions.

3.1 Road Inventory Survey

The inventory survey was carried out on the representative section, BCD of the selected branch, ACDEF (as defined in Figure 3.2) paying particular attention to drainages and shoulders' conditions. Information herein will further help in making maintenance and rehabilitation decision.

3.2 PCI Evaluation Method

The process of measurement or evaluation of Pavement Condition Index include: Network/Branch identification and definition, Identification and selection of sections, Identification and selection of sample units, Distress density and Deduct Value computation, PCI computation, Identification of primary causes. This itinerary is simply represented with a flow chart shown in Figure below.

Figure 3.1 The Flowchart for Evaluation of PCI (Zafar et, al.)

3.3 Pavement Network, Branch and Section Definition

The network comprises of the entire paved roadway within the Federal Polytechnic Nasarawa, Nigeria. This road networkburtsoutto the North-South highway (that runs through Loko-Uwetu bridge).Nasarawa city is about 70km from Nigeria's capital, Abuja. Branch ABCDEF of the road was chosen for this study due to the fact that it is in worse condition than the other branches, which have recently been rehabilitated. Section BCD has equally been selected as a representative sample after the Inventory Survey because it had clear distresses than the others. See the figure below:

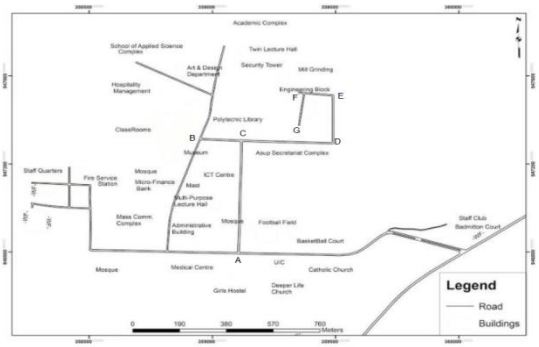

Figure 3.2 FPN Road Network, Branch and Section being Surveyed

3.4 Manual Pavement Condition Survey of Section BCD

Section BCD has been defined and condition survey has been conducted on it.

Sample Units in the Section

Before it is possible to start physical condition survey of a road section, it has to be segmented into smaller units called sample units. The size and number of sample unit has been determined as follows;

Table 3.1 Minimum Size of Sample Unit Allowable

AC Pavement Type	Allowable Sample Unit Area
Asphalt paved and unpaved roads	250 ± 100m2
Airfields	500 ± 200m2

Source: (Mosaberpanah, 2019).

And, minimum sample units to select for a section = 5

Section BCD was chosen because it bears the worst case scenario:

Taking N, Total number of sample units in the section = 20

Length of a sample unit = $\frac{517}{20}$ = 25.85m

By Rearranging: $[(25m\times 19) + 42 \times 1]$

25× 7.2 = 180m2>150m2, OK (see Table 3.1 above)
42× 7.2 = 302.4m2<350m2, OK (see Table 3.1 above)

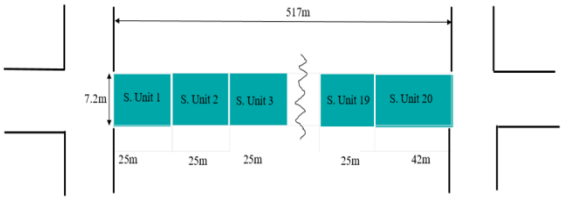

Figure 3.3 Total Sample Units in Section BCD

Determining the Number of Sample Units to be Surveyed, n:

$$n = \frac{(NS^2)}{[\frac{e^2}{4} \times (N-1) + S^2]}$$

N = Total number of sample units in the section
e = allowable error (5%, standard)
S = Standard Deviation of PCI between sample units (for AC Pavements=10)
∴ N = 20

$$n = \frac{(20 \times 10^2)}{[\frac{5^2}{4} \times (20-1) + 10^2]} = 9.14 \cong 10$$

OR, by determining n from the chart below:

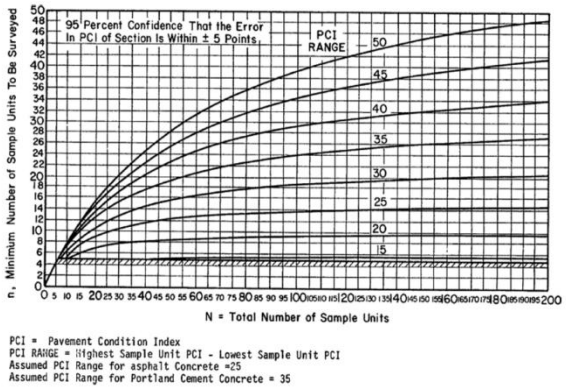

Figure 3.4 Determining the Number of Sample Units to be Surveyed, n(Hafizyar and Mosaberpanah, 2018).

Determining Sampling Interval, ì

$$ì = \frac{N}{n} = \frac{20}{10} = 2$$

Determining the Specific Sample Units to be Surveyed:
Selecting random start (r) between sample unit 1 and ì
ì, (i.e. 2) was therefore selected as random start:
Basic parameters for the systematic random sampling

Sample units to be surveyed (n) = 10

Sampling Interval (ì) = 2
Random Start (r) = 2

Hence:
r, r+ ì, r+2ì, r+3ì, r+4ì, r+5ì, r+6ì, r+7ì, r+8ì, r+9ì

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

Figure 3.5 Selected Sample Units to be Surveyed

3.5 Calculation of Pavement Condition Index

Now, when, the condition Survey has been completed for each selected sample unit, the results are used to estimate the PCI. The PCI calculation is established on the Deduct Values— weighing factors from 0 to 100 that specify the impact, each distress has on pavement condition.

The calculation steps for asphalt surfaced pavements are shortened in Figure 3.1. The following is an explanation of each step.

- Calculation of PCI for a Sample Unit

Step 1: Determining deduct value

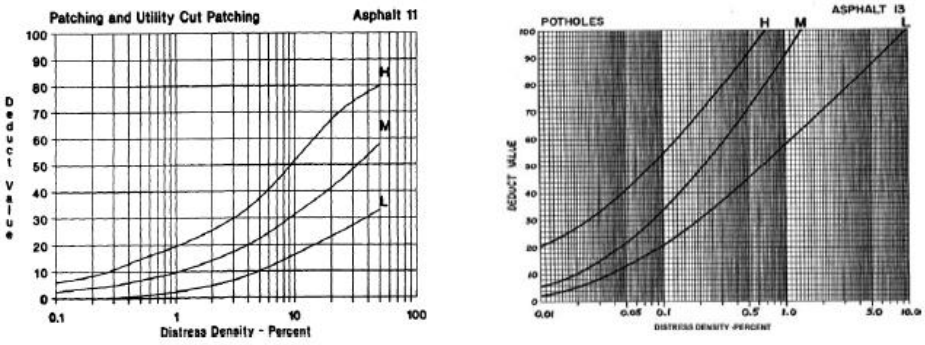

Figure 3.6 AC Pavement Deduct Curve for Patching and Potholes(Hafizyar and Mosaberpanah, 2018).

PAVEMENT CONDITION SURVEY DATA OBTAINED FROM THE FEDERAL POLYTECHNIC NASARAWA, NIGERIA FLEXIBLE ROAD NETWORK

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION DATA SHEET FOR SAMPLE UNIT			SKETCH: L W W= 7.2, L=25 A = 7.2 × 25 = 180m²			
BRANCH: ABCDEFG SURVEYED BY: M. S. Aliyu et. al	SECTION: BCD DATE: 12/05/21	SAMPLE UNIT: 2 SAMPLE UNIT AREA: 180m²				
1. Alligator Cracking (m²) 2. Bleeding (m²) 3. Block Cracking (m²) 4. Bumps and Sags (m²) 5. Corrugation (m²)	6. Depression (m²) 7. Edge Cracking (m) 8. Jt. Reflection Cracking (m) 9. Lane/Shoulder Drop Off (m) 10. Lon. & Trans. Cracking (m)	11. Patching & Utility Cut Patching (m²) 12. Polished Aggregate (m²) 13. Potholes (count) 14. Rail Road Crossing (m²) 15. Rutting (m²)	16. Shoving (m²) 17. Slippage Cracking (m²) 18. Swell (m²) 19. Weathering/Raveling(m²)			

DISTRESS TYPE/SEVERITY	QUANTITY						TOTAL	DENSITY (%)	DEDUCT VALUE
11M	3× 3.51	1.4× 1.5 × 7					25.2	14	35
13H	4						4	2.2	74

Figure 3.7 AC Pavement Data Sheet for Sample Unit 2

Step 2: Determine Max Allowable No of Deducts (mi)

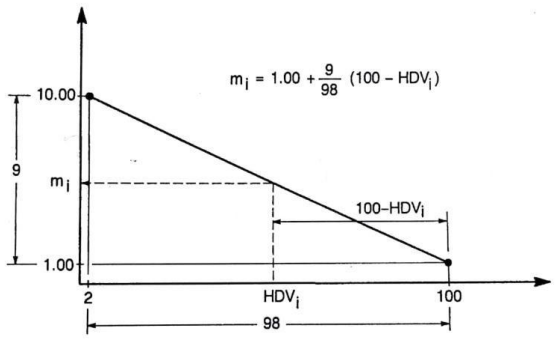

Figure 3.8 Determining Max Allowable No of Deducts(mi)(Mosaberpanah, 2019).

mi= 1 + (9/98)(100 – $HDVi$)

Where; mi = allowable number of deducts, including fractions.

HDVi = highest deduct value for a sample unit.

Step 3: Determining the Corrected Deduct Value (CDV)

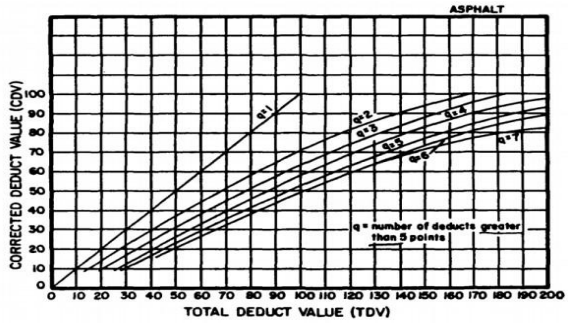

Figure 3.9 Corrected deduct value curves for asphalt-surfaced pavements (Hafizyar and Mosaberpanah, 2018)

Step 4: Calculation of PCI

Total PCI = ∑PCI(i)

Overall Average PCI =∑ PCI(i)/ N

The average PCI value determined from the formula above is the representation of the pavement condition index, PCI of the section under survey, section BCD.

IV. RESULTS AND DISCURSIONS

The results of the inventory survey and the pavement condition survey earlier conducted as described are hereby presented and discussed.

4.1 The Inventory Survey Result Discursion

After the inventory survey some of the information obtained therefrom are hereby presented and discussed.

Table 4.1 Road Inventory Survey Result

ROAD INVENTORY SURVEY DATA SHEET				
ROAD BRANCH: ABCDEFG		LOCATION: FED. POLY NAS.		
Road Component	Type	Average Width(m)	position	Present Condition
Carriageway	Paved road	7.2		Many distresses
Shoulder	Surface dressed	1.5	L & R	Visible subgrade in many areas
Footpath	None			
Verge	None			
Culvert/Drainage	Rectangular	0.6	L & R	Blocked culverts & collapsed drains at many points

4.2 The PC Survey Resultand Discursion

For sample Unit 2
TDV=110
HDV = 74
Mi = $\frac{Flexi.>2}{Rigid\ >5}$ (standard from figure…….)
Mi= 1+ ($\frac{9}{98}$) (100-HDVi)
= 1+ ($\frac{9}{98}$) (100-74) = 3.2
q = 3
CDV = 75 (from figure 3.8)
PCI= 100 – 75 = 25%
25% of the sample unit 2 is in good shape while the rest of the portion is in bad shape.
The summary of the results and discussion is as follows:

Table 4.12 PCI Values and Ratings of the Surveyed Sample Units

PCI VALUES OF FEDERAL POLY. NASARAWA ROAD, SECTION BCD (REPRESENTING BRANCH ABCDEF)				
S/N	SAMPLE UNIT NO	SAMPLE UNIT AREA (m2)	PCI (%)	PCI RATING
1	2	180	25	VERY POOR
2	4	‘’	52	FAIR
3	6	‘’	26	VERY POOR
4	8	‘’	25	VERY POOR
5	10	‘’	27	VERY POOR
6	12	‘’	60	FAIR
7	14	‘’	43	POOR

8	16	‘’	15	SERIOUS
9	18	‘’	48	POOR
10	20	302.4	27	VERY POOR

35% of section BCD road is in good shape, while the rest of the portion is in bad shape, and the PCI rating reveals that the pavement condition is VERY POOR (ASTM D6433-09, 2009).

Total PCI = ∑PCI(i) = (25+52+26+25+27+60+43+15+48+27) = 348 Overall Average PCI = ∑ PCI(i)/ N = 348/10 = 34.8%

4.3 The BEME Result and Discursion

ITEM	*DESCRIPTION*	*UNIT*	*QTY*	*RATE*	*AMOUNT (₦)*	*USD Equivalent*
1	*Allow for the cost of progress photograph and signage*	*Prov. Sum*			*20,000*	*48.63*
2	*Allow for payment of staff wages to daily rated project staff*	*Prov. Sum*			*150,000*	*364.74*
3	*Allow for the running cost and maintenance of project vehicles or motor boats for the supervisory staff as*	*Prov. Sum*			*200,000*	*486.32*
4	*Allow for the provision of road furniture including line marking as directed*	*Prov. Sum*			*100,000*	*243.16*
5	*Allow for the provision of miscellaneous services to the Engineer’s representative*	*Prov. Sum*			*100,000*	*243.16*
	TOTAL PAC CARRIED TO SUMMARY				*570,000*	*1,142.85*

ITEMS	*DESCRIPTION*	*UNIT*	*QTY*	*RATE*	*AMOUNT (₦)*	*USD Equivalent*
6	*Clear site on either side of centerline of road up to limit of construction*	m^2	*11,016*	*3*	*33,048*	*80.36*
7	*Scarify failed sections of existing asphalt surface (depth of excavation not exceeding 100mm) and cart to spoil on stock for reuse, shape and compact to 100% B.S compaction*	m^2	*99*	*460*	*45,540*	*110.74*
8	*Ditto item 2.03A but deph not exceeding 100mm*	m^2	*50*	*900*	*45,000*	*109.42*
9	*Excavate any materials except rock in cutting culverts, side drain and turnout and haul to spoil as directed*	m^3	*15.5*	*2000*	*31,000*	*75.38*

10	*Desilt sand and debris from culvert and drains to an average depth of 750mm and cart to spoil*	m^3	*35.2*	*2000*	*70,000*	*170.21*
	TOTAL PAC CARRIED TO SUMMARY				*224,588*	*546.11*

ITEMS	*DESCRIPTION*	*UNIT*	*QTY*	*RATE*	*AMOUNT (₦)*	*USD Equivalent*
11	*Provide, spread, shape and compact to 100% WASC approved wet mixed crushed stone base to a compacted layer of 150mm.*	m^3	*9.9*	*21000*	*207,900*	*505.53*
12	*Ditto item but in potholes*	m^3	*5.6*		*117,600*	*285.96*
13	*Provide and spread prime coat surface MC1 cutback bitumen at the rate of 1.3Litre/m^2*	m^2	*11,016*	*650*	*7,160,400*	*17,411.31*
14	*Provide and lay asphaltic concrete wearing course to a compacted thickness of 40mm over the carriageway*	m^2	*11,016*	*5500*	*60,588,000*	*147,326.44*
	TOTAL PAC CARRIED TO SUMMARY				*68,073,900*	*165,529.44*
	SUB TOTAL				*68,868,488*	*167,218.40*
	7.5% VAT				*5,165,136.6*	*12541.38*
	GRAND TOTAL				*74,033,624.6*	*180,O70.82*

At Naira to USD exchange rate of 0.0024₦/$. Year-on-year inflation rate stands at 18.35% (NATIONAL BUREAU OF STATISTICS, NIGERIA July, 2022)

Based on the current inflation rate, the grand sum of the suggested rehabilitation works would have been 213,383.92USD instead of 180,070.82USD, one year from now. The new amount would further rise due to impending deterioration of the pavement. At failure, reconstruction would have cost about 960,000USD per kilometre in Africa (World Bank, 2018). This road branch being about 1.5km, it reconstruction will cost at least 1,440,000USD as against the meagre 180,070.82USD needed to fix the road now and prolong its lifecycle.

CONCLUSION

At the end of the analysis the following conclusions have been made:

The inventory survey has revealed: poor road shoulder condition that will definitely affect riders' comfort especially when the need arises for emergency pullover;

Blocked drainages means that there is increased runoff on the road shoulders and carriageway which could result to excessive erosion;

Lack of footpath on the road means less comfort for pedestrians and cyclists;
Absence of verge indicates that there is poor landscaping around the roadway;

The pavement condition survey has revealed: generally VERY POOR condition of the road section based on the average PCI value of 35%;

It therefore means that there is an urgent need for a periodic maintenance such as overlay after patching;

Cost analysis for the suggested maintenance operation was drafted using the current rates of materials and labour and the present condition of the pavement. It cannot therefore be a representation of cost to be incurred as a result of delay in carrying out maintenance and rehabilitation exercise.

V. RECOMMENDATION

From the conclusions reached, the following recommendations have been made:
All the distresses on the entire branch (ABCDEFG) of the road network (inclusive of shoulders and drainages) should be mended after which an overlay with reasonable thickness (at least 40mm compacted thickness) be provided;

The Department of Civil Engineering Technology, Federal Polytechnic Nasarawa should reach out to the institution's top management through the Director of Works and Maintenance with such a proposal and show them the immediate and long-term implications of not embarking on the work immediately;

Conducting PCI assessment should be encouraged within a given time duration (average of two years) to prevent governments and institutions from incurring huge pavement Maintenance and Rehabilitation or reconstruction costs;

To ensure effective pavement sustainability and economic maintenance and rehabilitation, authorities concerned should implement within time, the recommendations of such researches as this.

VI. NOMENCLATURE

ACRONYMS	MEANING
PCI	Pavement Condition Survey
PMS	Pavement Management System
M&R	Maintenance and Rehabilitation
L (LSL)	Low Severity Level
M (MSL)	Medium Severity Level
H (HSL)	High Severity Level
DV	Deduct Value
TDV	Total Deduct Value
HDV	Highest Deduct Value
CDV	Corrected Deduct Value
BEME	Bill of Engineering Measurement and Evaluation

VII. ACKNOWLEDGEMENT

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