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A Simplified PCI-Based Condition Rating System for a Developing Country

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Abstract: Most developing countries face the challenge of inability to successfully adopt sophisticated commercial Pavement Information and Management System (PIMS) that incorporates pavement condition rating system. While, cities with populations of <22,500 can easily function using a manually-operated simplified PIMS, agencies with bigger population and bigger road network to manage, have to use computerized PIMS to effectively deal with the voluminous amount of generated data. The major challenge of this research therefore, was to accurately computerize the manual PCI-based condition rating system and make it user-friendly and effective for pavement management. A source code was developed within MATLAB software and used for computations while, Visual Basic programme was incorporated for the graphical display of results and generated reports. In order to validate, the constructed condition rating system, 12 road sections were selected and surveyed. Condition rating was performed for these road sections using both manual method and the constructed computerized system. The comparison of the results shows that the constructed system is quite reliable as a PCI-based condition rating system.

Key words: Pavement Condition Index (PCI), condition rating system, PIMS, distress deduction curves, polished aggregated, shoving

INTRODUCTION

The American Association of State Highway and Transportation Officials (AASHTO, 1990) Guidelines for PIMS defines PIMS as a set of tools or methods that (can) assist decision makers in finding cost-effective strategies for providing, evaluating and maintaining pavements in serviceable condition. The objective of pavement management is to constantly study or evaluate the service performance or what takes place between the initial construction and before failure. It is the period of preventive maintenance or preservation of pavement in order to assist pavement live up to its design life.

In addition, a PIMS provides a systematic process for collecting, managing, analyzing and summarizing pavement information to support the selection and implementation of cost-effective pavement construction, rehabilitation and maintenance programs (FHWA, 1993). To effectively support these types of decisions, a PIMS must include reliable and sufficient data; calibrated analysis models and procedures and effective, easy-to-use tools that help visualize and quantify the impact of the possible solutions considered.

The road transport infrastructure in Nigeria consists of 34, 340.95 km of federal highways (FMWH, 1999). A simplified PIMS was developed for this system of federal highways. The condition rating system part is PCI-based. The capabilities of the condition rating systems include ability to archive an inventory of physical pavement features including the number of lanes, length, width, surface type, functional classification and shoulder information for all the rural highway sections, ability to take pavement condition survey data and generate condition rating and ability to display photographs and video recording of observed distresses along any selected highway section.

The system is designed to operate with manual visual condition survey of the pavements. Collated field distress data can be entered in and the system automatically carries out PCI procedure and generates PCI condition rating for the particular road section. The system thereafter recommends suggested appropriate maintenance and rehabilitation strategies. Provision is also made for the storage and display of photographs and video shots of distresses taken during the survey.

Pavement condition rating systems: Based on measurements of roughness, surface distress, skid resistance and deflection, pavements can be assigned a score that reflects their overall condition. This score, sometimes called a pavement condition rating, quantifies a pavement's overall performance and can be used to help manage pavement networks. By carefully choosing the rating scale (called the condition index), pavement condition scores can be used by WAPA (2002). Trigger treatment, determine the extent and cost of repair, Determine a network condition index and allow equal comparison of different pavements.

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Pavement Condition Index (PCI): The PCI is an objective and repeatable rating of pavement condition based on observable distress. PCI is defined as an index reflecting the composite effects of varying distress types, severity level and extent upon the overall condition of pavement. PCI procedures for roads, parking lots and airfield pavements have been developed (ASTM, 1999).

PCI values range from 0-100, which are defined as failed and excellent condition, respectively. A PCI of 100 represents a pavement completely free of distress while, a PCI of 0 corresponds to a pavement that has failed completely and can no longer be driven safely at the designed speed.

The PCI value is decreased by a cumulative deduct value score based upon the type, quantity and severity level of distress and type of pavement. In terms of benefits and savings, network-level management tools such as PCI, help personnel develop rational budget requests and allocate optimal budget assignments.

MATERIALS AND METHODS

Section information page: The branch/section code identifies the segment of the road network whose basic information is needed. Here information page, information about any road section within the federal roads network can be retrieved. Such information include inventory of physical pavement features such as number of lanes, length, width, surface type, road classification and pavement materials information (Fig. 1).

Other retrievable road information includes construction and maintenance history of any particular road section. Also on this page, new record can be created (for a road section newly added to the network); existing record for a road section can also be updated. Additionally, the total number of samples and exact number of samples to be surveyed for any road section are automatically calculated by the system based upon the user input of sample area, length and width of the road. Lastly, the operating traffic (ADT) and percentage of trucks data could also be added.

In order to validate, the proper working of the form, all available information from the FMWH (1999) inventory for all the pavements in the network were input into the database. Such information included state, zone, route number (branch ID), road class (trunk route, secondary route, branch route and spur), branch length, carriageway width, type of surfacing (asphalt concrete, surface dressed and earth), sub-base/base materials and shoulder

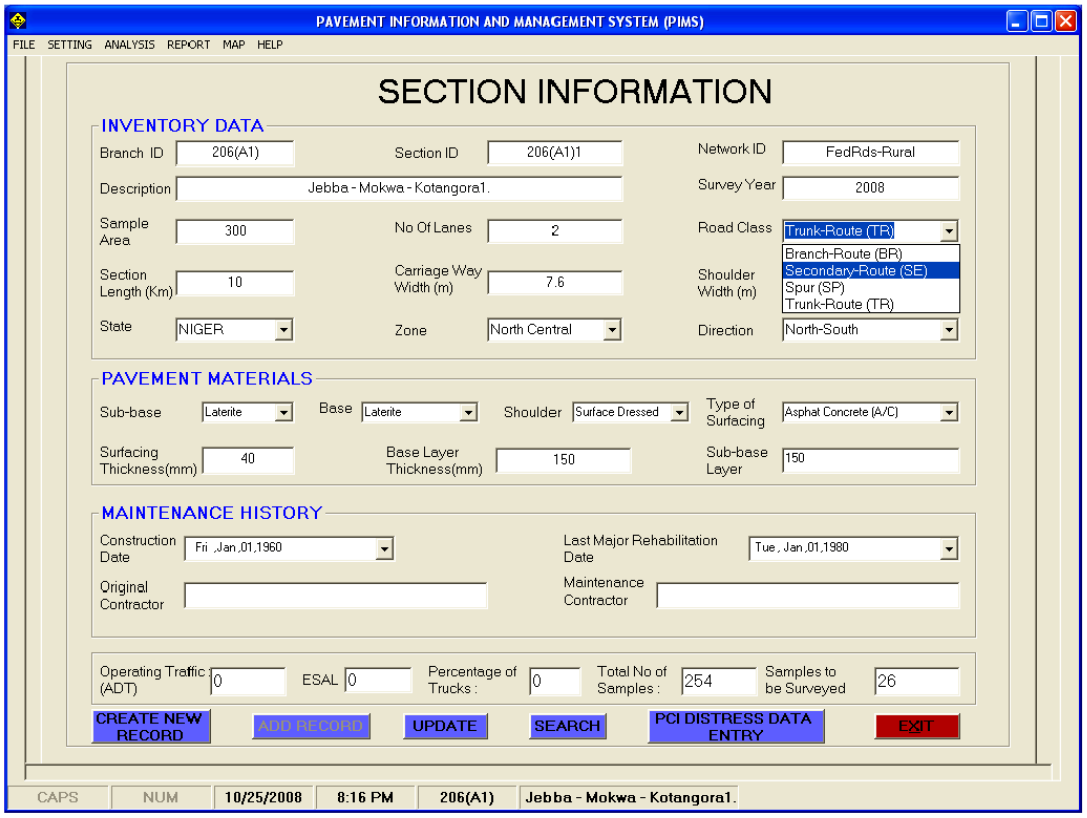


Fig. 1: Display of data information for a selected (case-study) road section

Table 1: Highway pavement sections selected for visual condition survey

Description	Zone	Length ($\times 10^3$m) A	Width (m) B	Area (m^2) A×B	Total No. samples	No. random samples	No. additional samples
Jebba-Mokwa-Kotangora road (section I)	North central	10.0	7.8	78.0	260	26	2
Mokwa-Makera road	North central	52.2	7.8	407.2	1357	136	-
Makera-Kasanga road	North central	34.0	11.2	380.8	1269	126	-
Kasanga-Tegina road	North central	22.0	11.2	248.6	828	82	1
Tegina-Ikerebodo road	North central	16.8	7.5	126.0	420	42	-
Ikerebodo-Birnin Gwari road	North central	52.2	7.5	391.5	1305	130	-
Egbe-Omu Aran road	North central	42.0	7.3	306.6	1022	102	1
Ajaokuta-Adumu road	North central	38.8	10.2	395.7	1319	131	-
Adumu-Ayingba road	North central	44.3	10.2	451.8	1506	150	-
Maje-Suleja-Madalla road	North central	17.2	7.3	125.5	420	42	-
Tegina-Zungeru road	North central	39.0	8.0	312.0	1040	104	-
Zungeru-Minna road	North central	42.6	8.0	340.8	1136	113	-

type (surfaced dressed, grassed or none). In all, a total of over 5000 units of inventory data for the federal roads have been entered.

Notes on displayed data for a selected road section: The following points should be noted, in respect to the displayed data for any selected road section:

- Data information will automatically be loaded up and displayed for a road section from the information stored in system's database
- It is possible to alter any existing data or update missing data. Thereafter, the update tab is clicked to save the changes into the database
- For any road within the network, there are four possible road classifications available, namely: Trunk Route (TR), Branch Route (BR), Secondary route (SE) and Spur (SP). The system allows for the classification of a road to be changed and updated accordingly
- Each road section in the network has been appropriately assigned (within the database), the state and zone to which, it belongs. However, should this data change in the future, it is possible for a user to effect necessary changes by clicking on the down-pointing arrow and selecting a new data from the displayed list
- The available options for sub-base materials are laterite and sand fill
- The available options for base materials are: crushed stone, laterite, soil cement, sand/bitumen. The available options for shoulder materials are: surfaced dressed and grass
- The available options for type of surfacing materials are Asphalt Concrete (A/C), Surface Dressed (S/D) and Earth
- To update existing construction and maintenance dates or input afresh, the user clicks on the down-pointing arrow besides these options and a calendar displays. The year, month and day required can then be easily selected

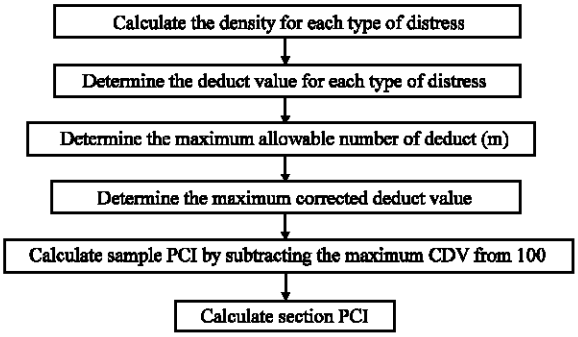


Fig. 2: Flowchart of the procedure to calculate section PCI (compiled)

Performing the visual pavement condition survey: The key to a successful evaluation is to identify the different types and severity levels of pavement distresses for each type of pavement such that the actual condition of the pavement is defined and applied to calculate PCI. A visual condition survey of 12 selected highway pavement sections (Table 1) was carried out in the month of August 2008 according to the procedure in ASTM D6433 (AASHTO, 2001). The ASTM D6433 procedure for performing pavement condition survey is represented in Fig. 2. The list of pavement distresses considered (typical for Nigerian roads) is shown in Table 2. These distresses were incorporated into the condition rating system.

Distress deduction curve automation: The manual calculation of the PCI procedure requires reading off deduct values from the distress deduction curves (14 No.) and reading off the Corrected Deduct Value (CDV) from the correction curves (1 No.). The challenge here was how to accurately transform these curves (on paper) into corresponding functions within the MATLAB program.

For the various distress curves used, about 30 distinct points (x, y) were taken on each. The points were used to redevelop a function corresponding to the curve. This was accomplished using Piecewise Cubic Hermite Interpolating Polynomial (PCHIP) available in MATLAB environment.

PP = pchip (X, Y) provides the piecewise polynomial form of a certain shape-preserving piecewise cubic hermite interpolant, to the values Y at the sites X to be later used with ppval (). X can be a row or column vector. Y is a row or column vector of the same length as X. If Y is a vector, then Y (j) is taken as the value to be matched at X (j), hence, Y must be of the same length as X.

PCHIP finds the values of an underlying interpolating function p (x) at intermediate points, such that:

- On each sub-interval,x (k)≤x≤x (k+1), p(x) is the cubic hermite interpolant to the given values and certain slopes at the two endpoints
- The slopes at the X (j) are chosen in such a way that:
  - p(x) is shape preserving and respects monotonicity. This means that on intervals where the data is monotonic, so is p(x)
  - At points where the data have a local extremum, so does p(x)

Figure 3 is the representation of the block cracking distress deduction curves developed using the function above, which is a replica of the curve on paper.

Using this concept, a function was written each for the distress curve. All these were then compiled up into a dynamic link library file (dll) that is referenced in the Visual Basic application. This was achieved using the Component Object Model (COM), which provides a framework for integrating reusable, binary software components into an application.

PCI calculation for the selected and surveyed road sections: The PCI procedure (Fig. 2) was used to manually calculate the PCI for all the surveyed samples for Jebba-Mokwa-Kotangora road. The section PCIs were then generated from the sample PCI results. Thereafter, the constructed condition rating system was also utilized to calculate the sample and section PCIs for all the selected and surveyed road sections. The two set of results from both manual and automated computations are compared as shown in Table 3 and 4.

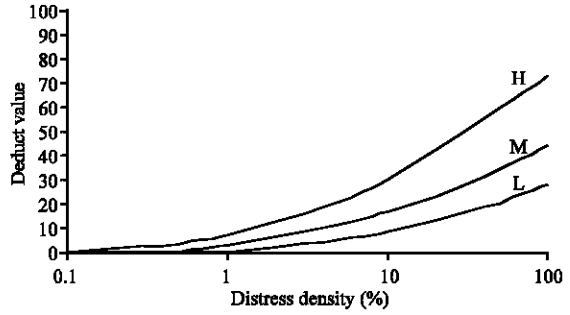


Fig. 3: Graph representation of developed block cracking distress deduction curves

Setting current cost values for the M and R options: After loading the data for a particular road section in the section information page and prior to moving to the PCI analysis section, it is desirable to input the current costs (per km) for the various maintenance and rehabilitation activities.

Table 2: Asphalt concrete surfaced pavement distress types

Distress Id	Distress type	Unit of measure	Define severity levels
1	Alligator cracking	m^2	Yes
2	Bleeding	m^2	Yes
3	Block cracking	m^2	Yes
4	Corrugation	m^2	Yes
5	Depression	m^2	Yes
6	Edge cracking	m^2	Yes
7	Lane/shoulder drop off	Linear meter	Yes
8	Longitudinal and transverse cracking	Linear meter	Yes
9	Patching	m^2	Yes
10	Polished aggregate	m^2	No
11	Potholes	Number (N)	Yes
12	Rutting	m^2	Yes
13	Shoving	m^2	Yes
14	Weathering and ravelling	m^2	Yes

Source: AASHTO (2001)

Table 3: PCI results for the surveyed Jebba-Mokwa-Kotangora (Section I) road

Type of sample	Sample PCI (manual)	Automated sample PCI (using PIMS)
Representative	45.0	45.54
Representative	44.2	45.15
Representative	70.0	70.00
Representative	62.0	62.63
Representative	87.0	86.25
Representative	28.0	29.17
Representative	45.0	45.31
Representative	39.5	38.97
Representative	41.0	40.93
Representative	25.5	27.05
Representative	67.0	67.99
Representative	27.0	40.05
Representative	34.5	35.14
Representative	36.0	37.17
Representative	32.0	48.21
Representative	88.0	88.99
Representative	58.0	59.17
Representative	28.0	30.23
Representative	76.0	77.82
Representative	67.0	66.67
Representative	28.0	29.03
Representative	24.0	23.97
Representative	53.0	52.86
Representative	32.0	30.31
Representative	72.0	71.85
Representative	59.0	57.50
Additional	23.0	22.24
Additional	8.0	9.18
Section PCI	48.0	47.83
Mean	46.0	48.00
SD	21.1	20.47
COV*	0.5	0.40

*Coefficient of Variation (COV) = SD/Mean

The user selects the SETTING menu option from the menu toolbar. The SETTING... dialogue box displays (Fig. 4). By clicking on the edit button, the user is allowed to input current values for the various M and R options. Thereafter, the save button is clicked to save the input (The current default rates provided are based on year 2008 average going rates obtained from Lagos State and Federal Ministries of Transportation).

PCI distress data form: Next, the user selects the PCI distress data entry button (lower right corner) to load the PCI distress data form (Fig. 5). The upper part of the form contains information for the selected road section and this information is automatically loaded up, if available, from the database.

The lower part of the PCI distress data form allows the user to input the survey data captured for the various samples taken from site. The sample area, sample unit number, sample type, distress type, distress severity and quantity are the necessary user input. The user selects the distress type first, followed by the distress severity and then input the distress quantity for every sample of road surveyed. The information is transferred from the site survey sheets.

After all the distress data for a sample have been entered, the user clicks on sample computation to perform the analysis. Immediately, the Total Deduct Value (TDV), Corrected Deduct Value (CDV), sample PCI value and sample rating are generated and displayed.

Other operations within the PCI distress data form interface: Some other operations that could be carried out within the PCI distress data form interface include:

Next sample: This button allows the user to proceed to the next sample until all samples have been treated.

Table 4: PCI results for some selected and surveyed road sections

Description	Section PCI (manual)	Automated section PCI (using pims)
Jebba-Mokwa-Kotangora road (setion I)	48.0	47.83
Mokwa-Makera road	55.0	54.24
Makera-Kasanga road	49.0	49.35
Kasanga-Tegina road	58.0	57.46
Tegina-Ikerebodo road	66.0	65.85
Ikerebodo-Birnin Gwari road	64.0	63.48
Egbe-Omu Aran road	35.0	36.25
Ajaokuta-Adumu road	37.0	36.67
Adumu-Ayingba road	40.0	41.05
Maje-Suleja-Madalla road	56.0	55.25
Tegina-Zungeru road	53.0	52.36
Zungeru-Minna road	62.0	61.34
Mean	52.0	52.00
SD	10.4	9.90
COV*	0.2	0.20

*Coefficient of Variation (COV) = SD/Mean

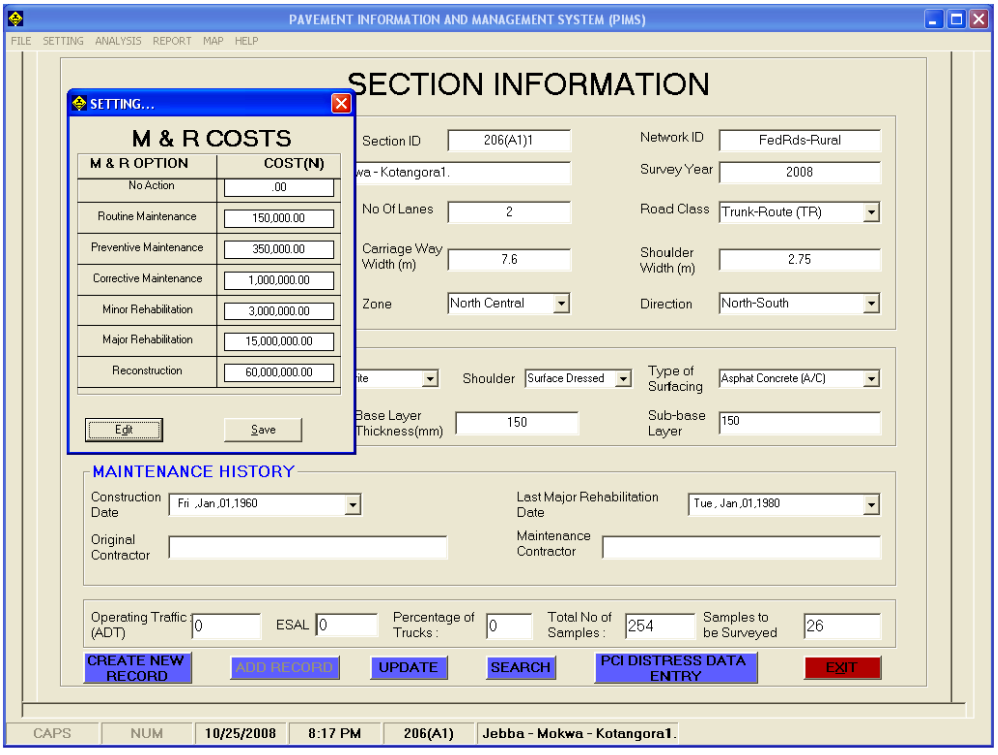


Fig. 4: Entering current values for the M and R options

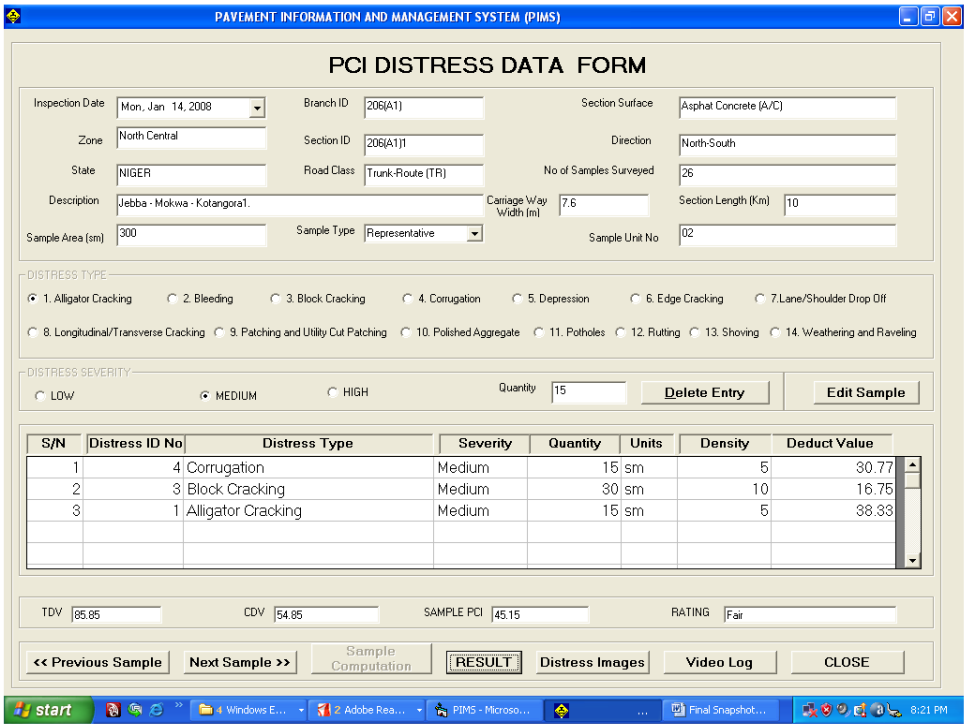


Fig. 5: PCI distress data form interface

Previous sample: This button gives the user to chance to navigate to previous samples to view and/or effect corrections.

Edit sample: By clicking on this button, the user has the flexibility to edit data input previously entered.

Result button: This button displays the final results for all samples keyed in. It opens the result page (Fig. 6).

Distress image/video log buttons: Selecting either of these buttons opens a page where images and video log of distresses captured on site can be viewed (Fig. 7).

Automated PCI calculation results page: The Automated PCI calculation results page (Fig. 6) shows the results of automated PCI calculation. It provides the section PCI value, PCI category and the standard deviation value. M and R strategy is automatically recommended based on the generated section PCI (Table 5). A corresponding M and R cost is also automatically provided for the generated strategy based on the values previously provided by the user under SETTING (Fig. 4). This result page also provides a listing of all the samples considered in the PCI calculations. Finally, the user has the option to print the output directly or save to file for later printing.

Table 5: M and R strategies and corresponding estimated costs

Section PCI range	M and R strategy	Estimated cost of M and R activity/km ($\times 10^6$)
95-100	No action	0.0
86-95	Routine maintenance	2.5
71-85	Preventive maintenance	4.0
56-70	Corrective maintenance	6.0
46-55	Minor rehabilitation	8.5
26-45	Major rehabilitation	11.0
0-25	Reconstruction	20.0

Generating strategies for M and R actions: A comprehensive approach to pavement management requires the development and use of maintenance, rehabilitation and reconstruction strategies, in order to effectively maintain the roadway network. These M and R strategies, when combined with specific road condition information such as pavement condition survey, pavement riding quality and functional classification, lead to specific M and R actions.

Figure 8 presents suggested maintenance and rehabilitation feasible actions for flexible pavements. It should be noted, however that exact actions are site specific.

The broad M and R strategies needed for the roadway network will be determined based upon only the current PCI of pavements, therefore, the road maintenance agency will be able to roughly prepare or plan their budget at network level.

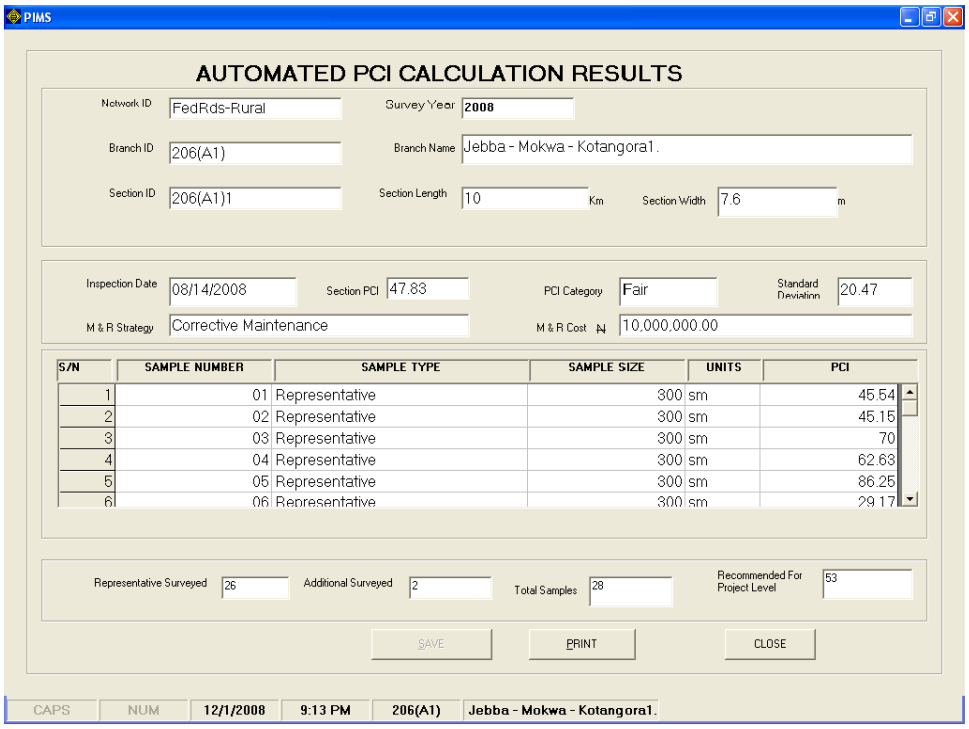


Fig. 6: Automated PCI calculation results page

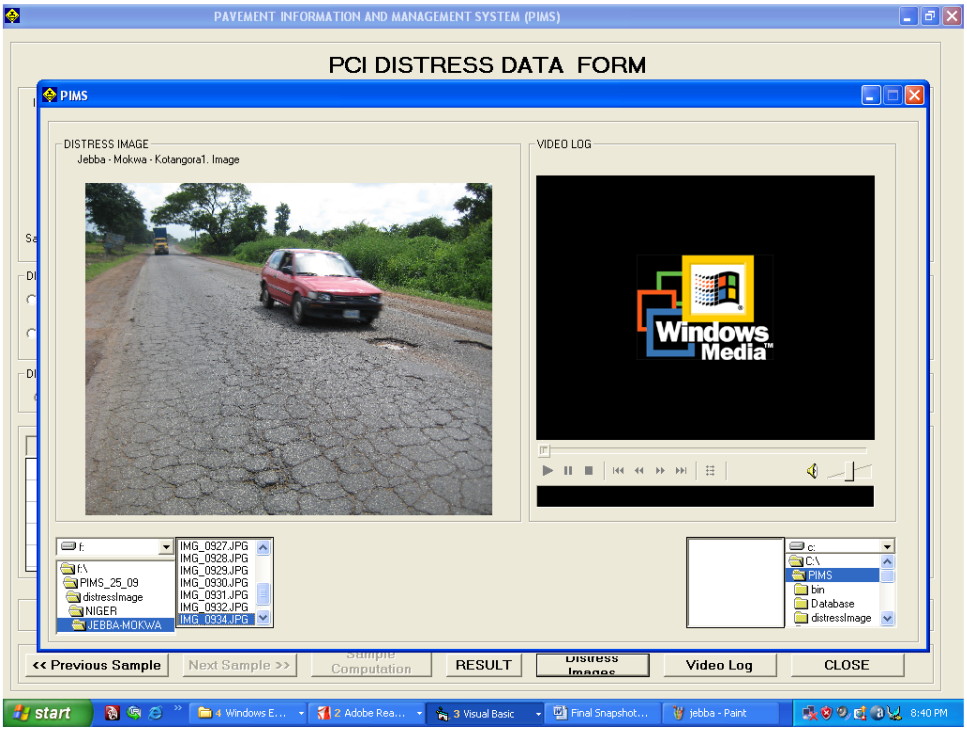


Fig. 7: Displays of images and videolog of distresses captured on site

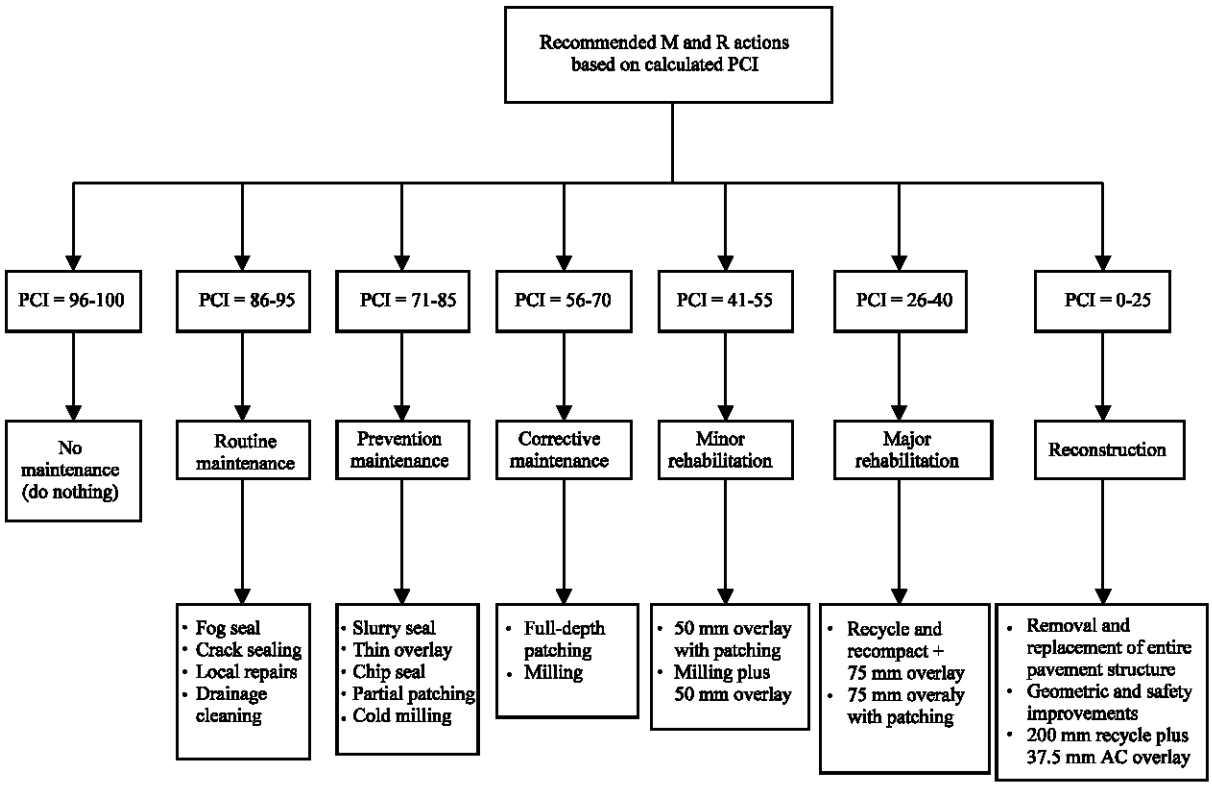


Fig. 8: Suggested M and R feasible actions for flexible pavements in Nigeria

RESULTS AND DISCUSSION

The constructed system is also capable of generating a series of condition reports that are useful to aid decision-makers in evaluating both the condition of individual road section and the overall condition of the entire network. The three condition reports that can be generated for all the pavements at the network level are section condition report, branch condition report and historic report.

Section condition reporting: The section condition report is designed to contain all the basic information pertinent to the section(s) of all related branches in the road network such as the state, zone and last inspection date. It also provides detailed information concerning the condition (average PCI), PCI standard deviation, M and R cost and PCI category. Reports could be displayed for the following categories:

All: If this option is selected, all the roads in the network (and database) are loaded up and listed (Fig. 9).

Survey year: A particular year is selected by the user and the results for all the roads surveyed in the selected year (Fig. 10).

State: With this option, the user can view the results for roads surveyed in any state of the federation (Fig. 11).

PCI category: If the user wishes to view reports on roads in the network according to PCI category, this option is selected (Fig. 12).

Zone: This option displays results for surveyed roads for a selected geopolitical zone in the country (Fig. 13).

For any category of report selected, the user can print hard copy by clicking on the print tab in the upper right corner of the interfaces.

Branch condition reporting: Branch condition reporting is very much similar to section condition reporting. The major difference is that branch reporting is an aggregated summary of the individual reports of the various sections that make up a branch. Figure 14 is an example of the display of branch condition report according to state category.

Historic condition reporting: Finally, the constructed system is also capable of displaying historic reports for some key parameters such as ADT, PCI, M and R Actions and costs. The user selects any of the listed parameters from the historic reports submenu (Fig. 15). Thereafter, the user is prompted to select the range of years, for which result is being sought for (Fig. 16).

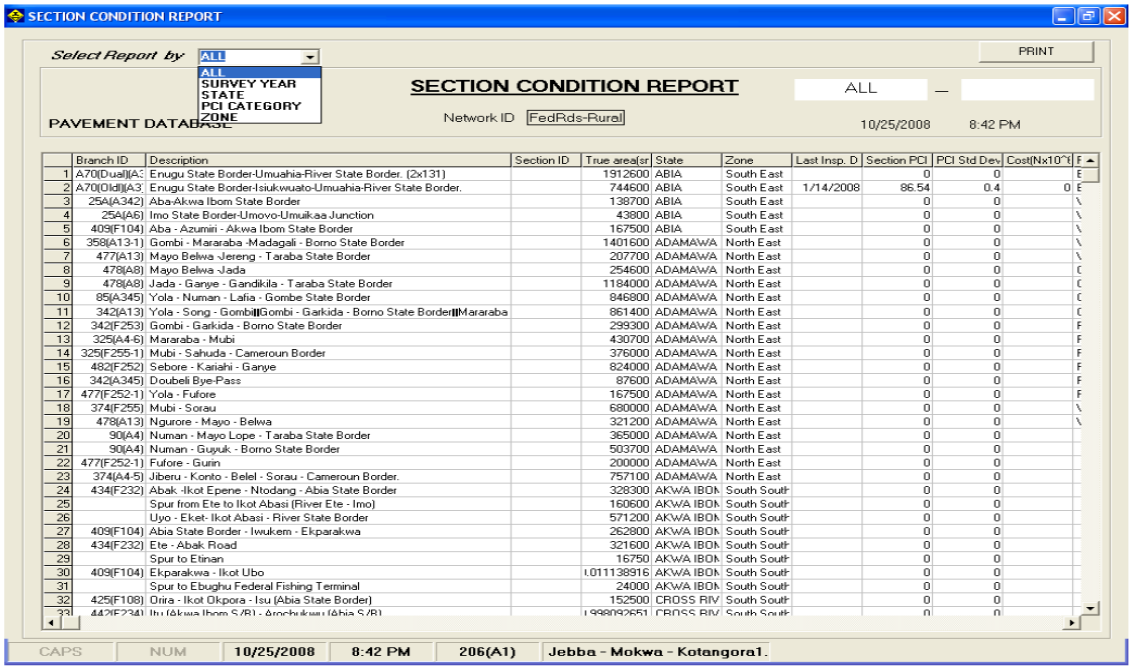


Fig. 9: Section condition report interface for All roads in the network

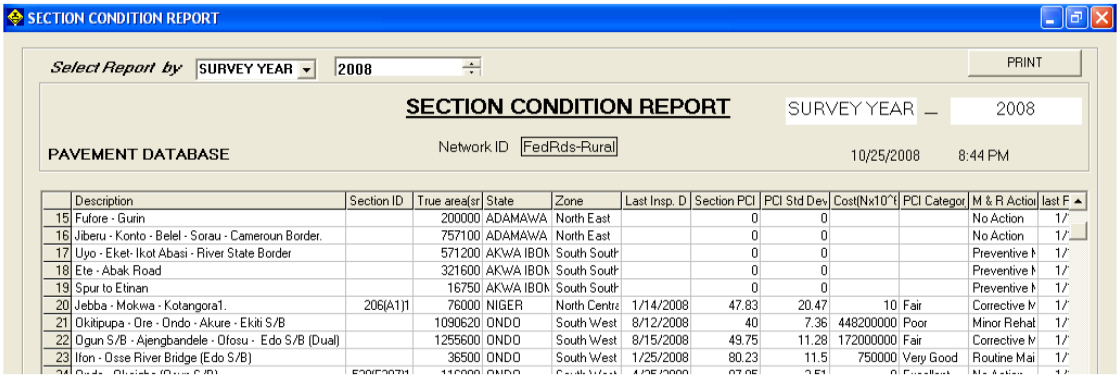


Fig. 10: Section condition report for roads surveyed in a selected year

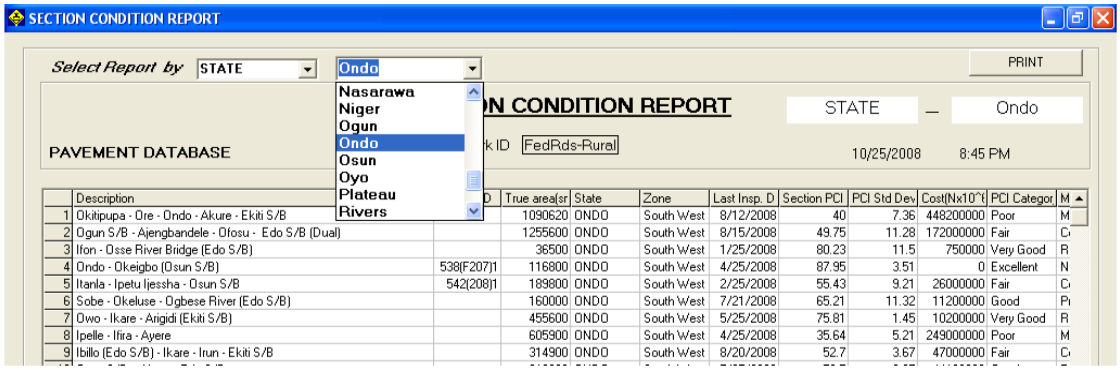
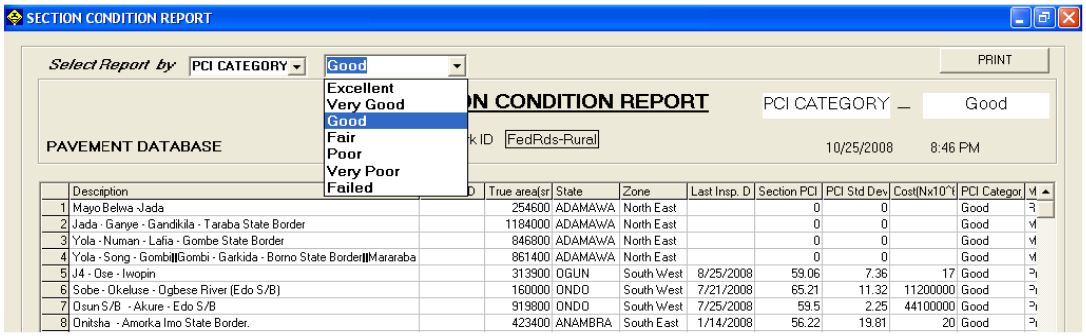
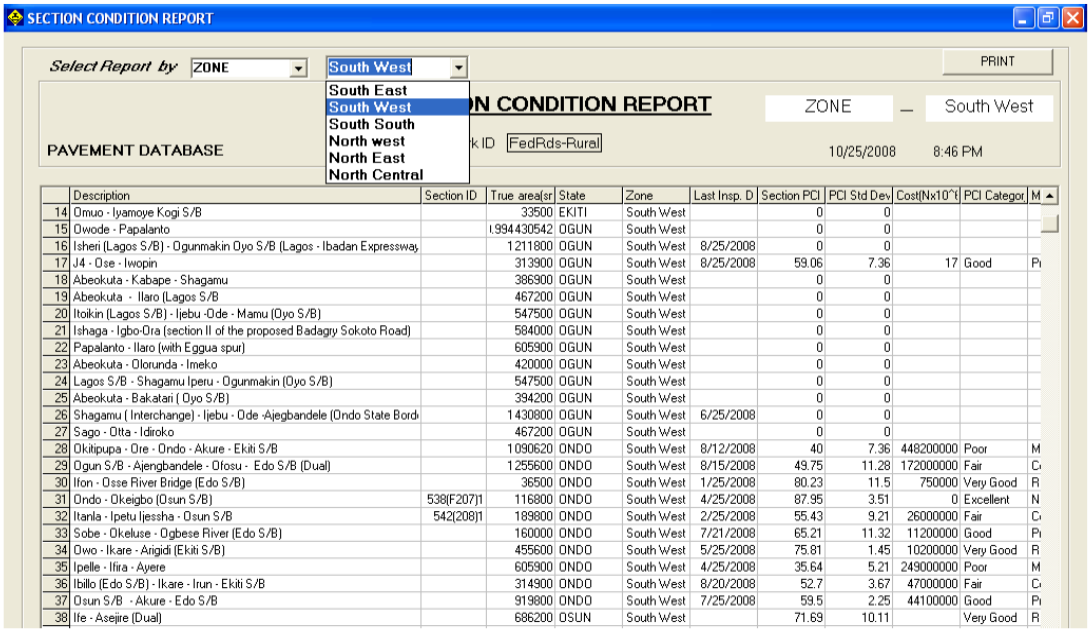


Fig. 11: Section condition report for roads surveyed in a selected state of the federation



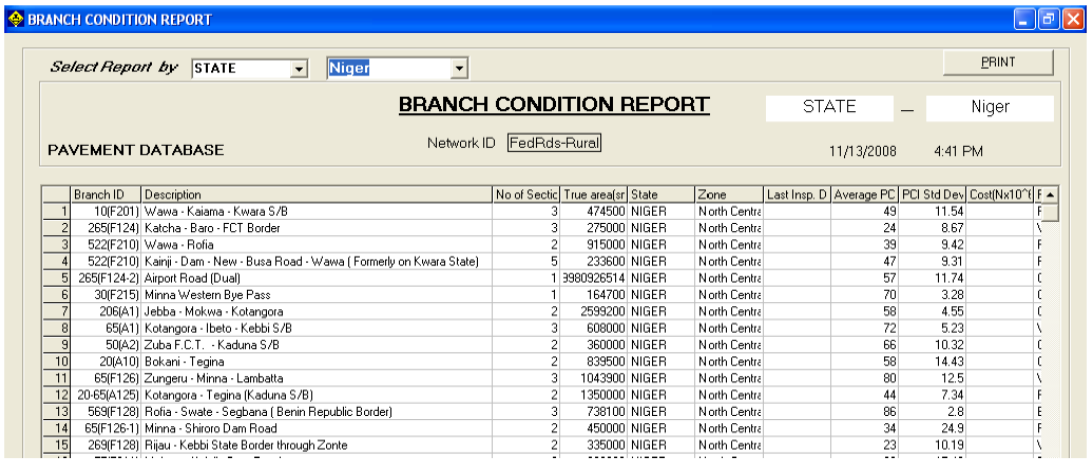
	Description	True area(sr	State	Zone	Last Insp. D	Section PCI	PCI Std Dev	Cost(Nx10^t	PCI Categor
1	Mayo Belwa -Jada	254600	ADAMAWA	North East		0	0		Good
2	Jada - Ganye - Gandikila - Taraba State Border	1184000	ADAMAWA	North East		0	0		Good
3	Yola - Numan - Lafia - Gombe State Border	846800	ADAMAWA	North East		0	0		Good
4	Yola - Song - Gombi‖Gombi - Garkida - Borno State Border‖Mararaba	861400	ADAMAWA	North East		0	0		Good
5	J4 - Ose - Iwopin	313900	OGUN	South West	8/25/2008	59.06	7.36	17	Good
6	Sobe - Okeluse - Ogbese River (Edo S/B)	160000	ONDO	South West	7/21/2008	65.21	11.32	11200000	Good
7	Osun S/B - Akure - Edo S/B	919800	ONDO	South West	7/25/2008	59.5	2.25	44100000	Good
8	Onitsha - Amorka Imo State Border.	423400	ANAMBRA	South East	1/14/2008	56.22	19.81	20	Good

Fig. 12: Section condition report for roads surveyed according to PCI category



	Description	Section ID	True area(sr	State	Zone	Last Insp. D	Section PCI	PCI Std Dev	Cost(Nx10^t	PCI Categor
14	Omuo - Iyamoye Kogi S/B		33500	EKITI	South West		0	0		
15	Owode - Papalanto		1.994430542	OGUN	South West		0	0		
16	Isheri (Lagos S/B) - Ogunmakin Oyo S/B (Lagos - Ibadan Expressway		1211800	OGUN	South West	8/25/2008	0	0		
17	J4 - Ose - Iwopin		313900	OGUN	South West	8/25/2008	59.06	7.36	17	Good
18	Abeokuta - Kabape - Shagamu		386900	OGUN	South West		0	0		
19	Abeokuta - Ilaro (Lagos S/B		467200	OGUN	South West		0	0		
20	Itoikin (Lagos S/B) - Ijebu -Ode - Mamu (Oyo S/B)		547500	OGUN	South West		0	0		
21	Ishaga - Igbo-Ora (section II of the proposed Badagry Sokoto Road)		584000	OGUN	South West		0	0		
22	Papalanto - Ilaro (with Eggua spur)		605900	OGUN	South West		0	0		
23	Abeokuta - Olorunda - Imeko		420000	OGUN	South West		0	0		
24	Lagos S/B - Shagamu Iperu - Ogunmakin (Oyo S/B)		547500	OGUN	South West		0	0		
25	Abeokuta - Bakatari (Oyo S/B)		394200	OGUN	South West		0	0		
26	Shagamu (Interchange) - Ijebu - Ode -Ajegbandele (Ondo State Bord		1430800	OGUN	South West	6/25/2008	0	0		
27	Sago - Otta - Idiroko		467200	OGUN	South West		0	0		
28	Okitipupa - Ore - Ondo - Akure - Ekiti S/B		1090620	ONDO	South West	8/12/2008	40	7.36	448200000	Poor
29	Ogun S/B - Ajengbandele - Ofosu - Edo S/B (Dual)		1255600	ONDO	South West	8/15/2008	49.75	11.28	172000000	Fair
30	Ifon - Osse River Bridge (Edo S/B)		36500	ONDO	South West	1/25/2008	80.23	11.5	750000	Very Good
31	Ondo - Okeigbo (Osun S/B)	538(F207)1	116800	ONDO	South West	4/25/2008	87.95	3.51	0	Excellent
32	Itanla - Ipetu Ijessha - Osun S/B	542(208)1	189800	ONDO	South West	2/25/2008	55.43	9.21	26000000	Fair
33	Sobe - Okeluse - Ogbese River (Edo S/B)		160000	ONDO	South West	7/21/2008	65.21	11.32	11200000	Good
34	Owo - Ikare - Arigidi (Ekiti S/B)		455600	ONDO	South West	5/25/2008	75.81	1.45	10200000	Very Good
35	Ipelle - Ifira - Ayere		605900	ONDO	South West	4/25/2008	35.64	5.21	249000000	Poor
36	Ibillo (Edo S/B) - Ikare - Irun - Ekiti S/B		314900	ONDO	South West	8/20/2008	52.7	3.67	47000000	Fair
37	Osun S/B - Akure - Edo S/B		919800	ONDO	South West	7/25/2008	59.5	2.25	44100000	Good
38	Ife - Asejire (Dual)		686200	OSUN	South West		71.69	10.11		Very Good

Fig. 13: Section condition report for roads surveyed according to geopolitical zone



	Branch ID	Description	No of Sectic	True area(sr	State	Zone	Last Insp. D	Average PC	PCI Std Dev	Cost(Nx10^t
1	10(F201)	Wawa - Kaiama - Kwara S/B	3	474500	NIGER	North Centre		49	11.54	
2	265(F124)	Katcha - Baro - FCT Border	3	275000	NIGER	North Centre		24	8.67	
3	522(F210)	Wawa - Rofia	2	915000	NIGER	North Centre		39	9.42	
4	522(F210)	Kainji - Dam - New - Busa Road - Wawa (Formerly on Kwara State)	5	233600	NIGER	North Centre		47	9.31	
5	265(F124-2)	Airport Road (Dual)	1	3980926514	NIGER	North Centre		57	11.74	
6	30(F215)	Minna Western Bye Pass	1	164700	NIGER	North Centre		70	3.28	
7	206(A1)	Jebba - Mokwa - Kotangora	2	2599200	NIGER	North Centre		58	4.55	
8	65(A1)	Kotangora - Ibeto - Kebbi S/B	3	608000	NIGER	North Centre		72	5.23	
9	50(A2)	Zuba F.C.T. - Kaduna S/B	2	360000	NIGER	North Centre		66	10.32	
10	20(A10)	Bokani - Tegina	2	839500	NIGER	North Centre		58	14.43	
11	65(F126)	Zungeru - Minna - Lambatta	3	1043900	NIGER	North Centre		80	12.5	
12	20-65(A125)	Kotangora - Tegina (Kaduna S/B)	2	1350000	NIGER	North Centre		44	7.34	
13	569(F128)	Rofia - Swate - Segbana (Benin Republic Border)	3	738100	NIGER	North Centre		86	2.8	
14	65(F126-1)	Minna - Shiroro Dam Road	2	450000	NIGER	North Centre		34	24.9	
15	269(F128)	Rijau - Kebbi State Border through Zonte	2	335000	NIGER	North Centre		23	10.19	

Fig. 14: Branch condition report for a selected state

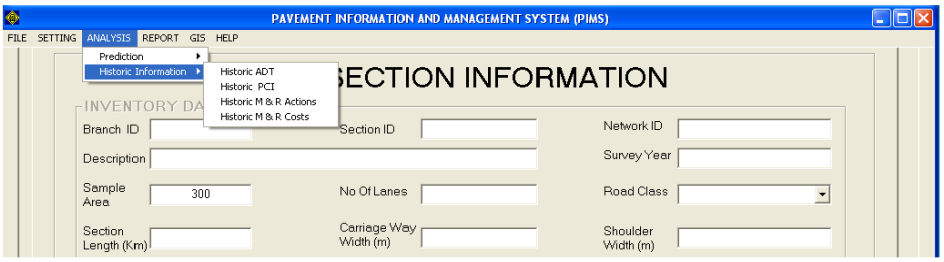


Fig. 15: Accessing the historic information module

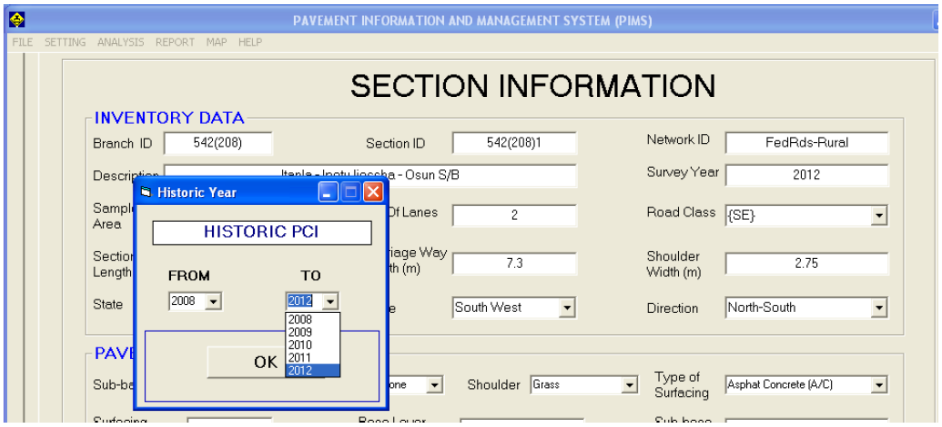


Fig. 16: Selection of the range of years for historic PCI report display

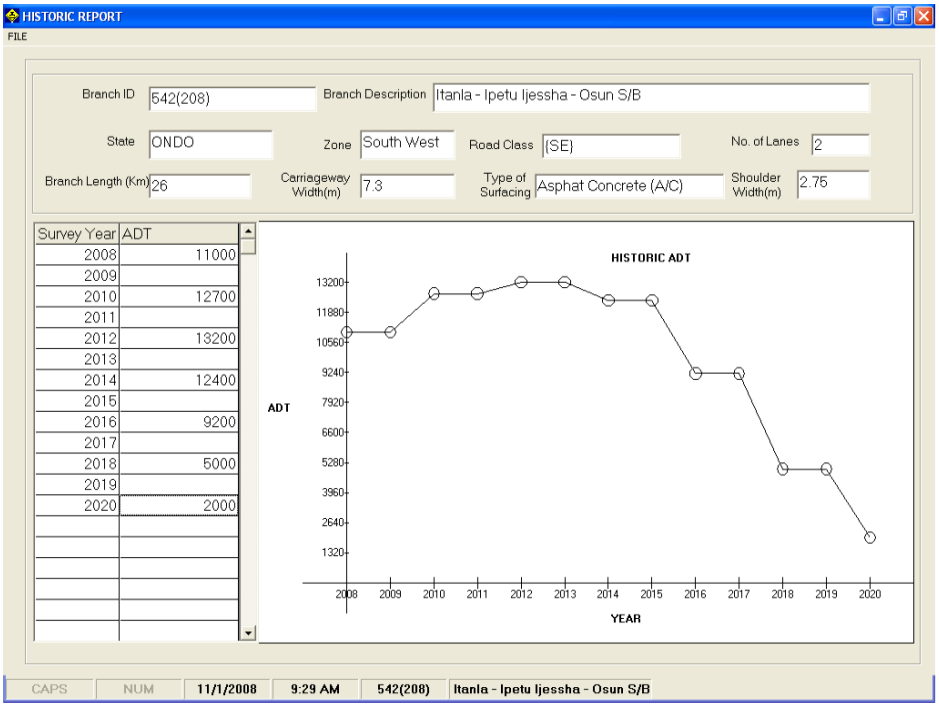


Fig. 17: Historic ADT report display for a selected road and range of years

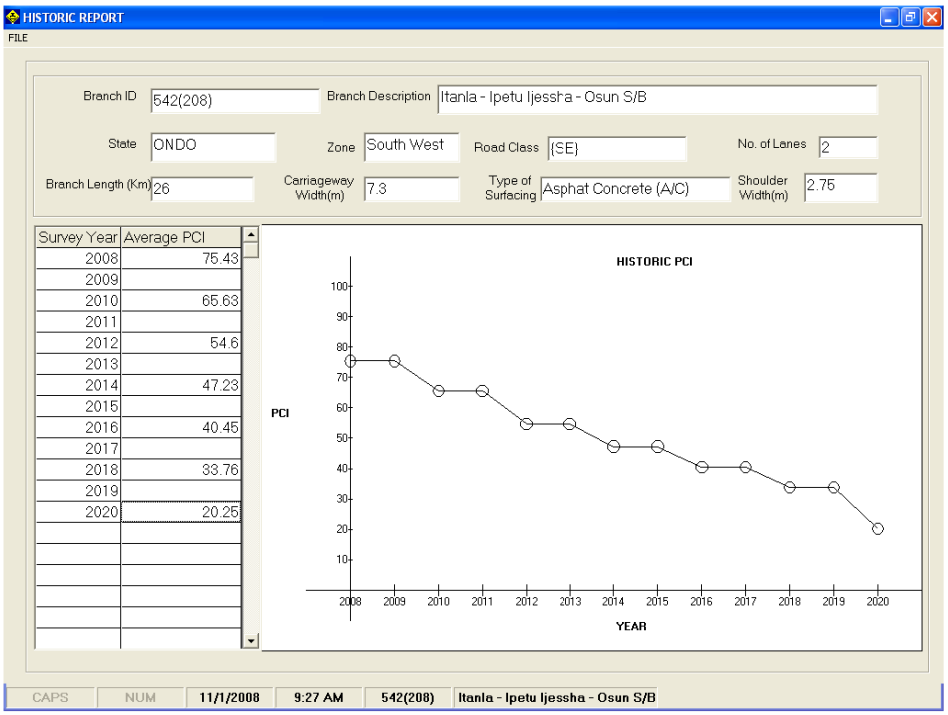


Fig. 18: Historic PCI report display for a selected road and range of years

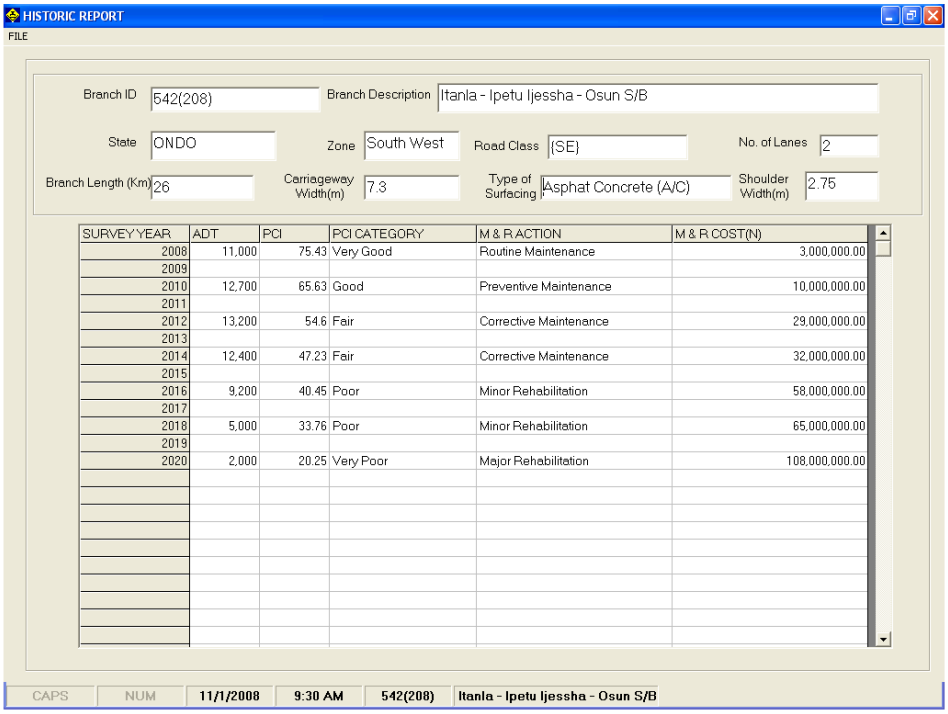


Fig. 19: Combined historic report display for a selected road and range of years

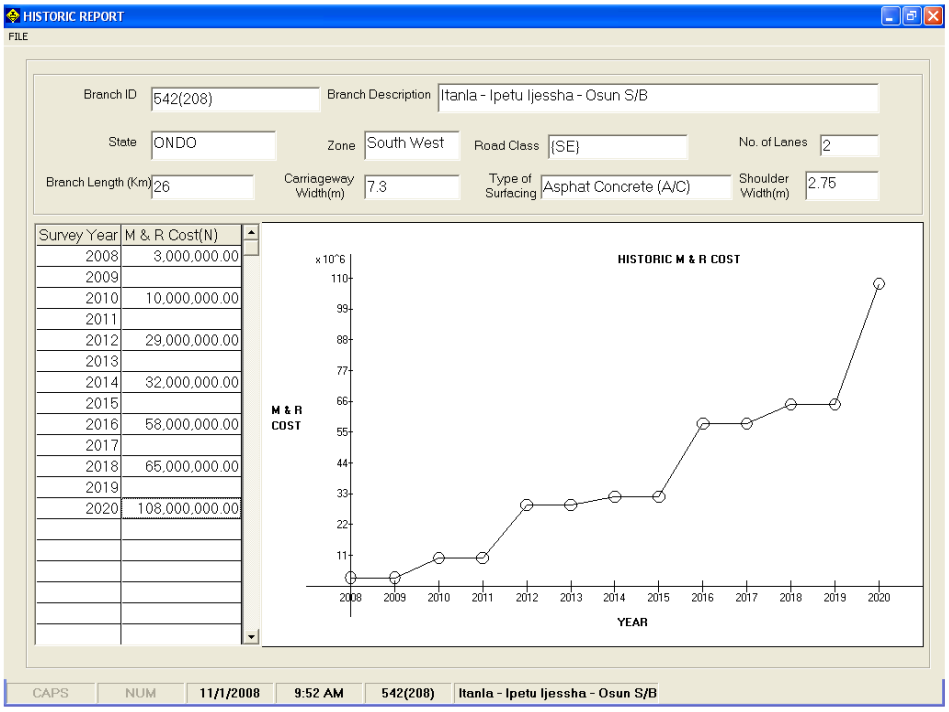


Fig. 20: Historic M and R costs report display for a selected road and range of years

The system subsequently plots and displays a graph of the stored values for the selected parameter, for the range of years selected. Figure 17-20 show the results of the historic data of ADT, PCI, M and R actions and costs respectively, from the year 2008-2020.

Summary: From the foregoing research, the following summary can be made:

- The constructed system is capable of generating series of condition reports under different categories. The federal roads maintenance agency can use such available information to observe the different locations and types of pavement M and R actions performed in a year
- The constructed system can assist decision-makers in the government to evaluate the impact of distribution of funds for M and R activities of all road sections. Evaluation can be done at state or zone level
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- Implementation of the constructed PIMS would help to encourage the adoption of effective but cheaper preventive maintenance of road pavements and thus, prevent deterioration of pavement to the level of costly reactive maintenance
- Plotted historic graphs are useful to observe the trend of the traffic or pavement condition and provide very useful information to pavement managers with just the touch of a button

CONCLUSION

It has been clearly demonstrated that the constructed system fulfils part of the objective of developing a condition rating system with the ability for easy storage and retrieval of relevant pavement information such as information on inventory data, pavement materials and maintenance history.

In order to validate the reliability of the constructed system, 12 road sections were selected and visually surveyed. The detailed manual and automated PCI results for the surveyed road sections are compared. The comparison of the two sets of results shows that the constructed system can reliably generate accurate PCI results for surveyed roads. The pictures and video recording of distresses as captured on site can be easily loaded into the system and displayed.

RECOMMENDATIONS

Regular measurement of the condition rating of some selected pavement sections should be carried out over a period of some years. Based on the generated model curves using historical data, future condition rating could then be predicted.

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