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Research Article

Evaluation of Pavement Condition Index for Roads of Al-Kut City

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Abstract

The operation and maintenance of highway network in Iraq continuously worsens in spite of the efforts and expenditures to improve their serviceability. The main reasons of highways network failure are the fast appearance and increase in the intensity of deformation with the absence of periodical maintenance. The objective of this research is to estimate the condition of flexible pavement through visual surveys using the Pavement Condition Index (PCI) method and can provides an easy way to calculate the PCI based on GIS data with Micro PAVER software 5.2. Ten roads (8 internal and 2 external) in Al-Kut city in the middle of Iraq were surveyed. The results were shown that three roads are in poor condition while others in fair and good condition. 117 sections of the study area are in good condition while 61 and 65 sections are in fair and poor condition respectively. It is important to create an annual road deteriorations database system and the resulting change in the PCI values which occurs every year.

Keywords*: Pavement Condition Index (PCI), GIS, Micro PAVER.*

1. Introduction

Pavement condition index (PCI) is one of the most widely used performance measurement of pavements; it has been used as an indicator of the pavement condition (Tighe *et al*., 2004; Uglova and Saenko, 2016). This index should include the quantity and severity for each type of distress. (ASTM, 2007).

Micro PAVER is the pavement management system adopted by the Federal Aviation Administration, US Army, US Air Force, US Navy and Air National Guard. It is a decision making tool for the development of cost effective maintenance and repair alternatives for roads and streets, parking lots, and airfields. (APWA, 2012).
This research is the first trial to calculate Pavement Condition Index (PCI) approach of quantifying pavement condition, for Al-Kut city. Taking advantage of the ability of GIS tools to store the completely information about severity, quantity, (x,y) coordinates, and location in the road for each distress type during the visual surveys and use these information in Micro PAVER application. Micro PAVER was used to decrease expected errors related to a conventional method (hand calculations).

2. Literature Review

It is necessary to know the condition of pavement from standpoint of setting up design criteria and for establishing maintenance and priority (Yoder and Witczak, 1975). It will serve several purposes such as, establishing need for including design requirements of procedures, and pointing out special conditions influencing overlay design (Finn and Monismith, 1984).

A condition survey is not concerned with determining the structural adequacy of a pavement and, generally, it does not attempt to provide reasons as to why the pavement is, or to indicate what the type of maintenance is required. Rather, it attempts to provide a comprehensive assessment of the reliability or acceptability of highway pavement sections as the might be judge by road users at a given time. As such, the results of a condition survey can be very valuable when determining priorities for maintenance funding within a major road system (O'Flaherty, 1988).

The PCI is a quick method of comparing the overall condition of pavement and magnitude of rehabilitation needs (Weil, 2009).

Obead, 2012 pointed out that the PCI can be used to identify when the treatments are needed, to define the condition state, for ranking or prioritization, and as the number used to forecast pavement condition. To assess pavement condition, PAVER system has capability to perform pavement condition analysis.

Faris and Mahir, 2012 stated that the maintenance of transportation assets has become a worst challenge for most of the transportation agencies over the world. Trikit-Tooz Road (in the middle of Iraq) was divided into segments to calculate PCI. Based on the results were concluded that managers will be able to compare three types of necessity; financial, physical, and

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specifications instructions, sometimes Condition Index refers to that assets able to be used for 15 years while specification refers that it can be used for 10 years only and so on. In the same way, Zaltuom (2011) calculated the PCI for roads network in Al-Koms city in Libya.

Vishwanath *et al*., (2013) used PCI as a measuring tool to determine the pavement maintenance strategies based on distress survey. It was provided a simple approach to develop PCI for the selected arterial road stretches for taking up cost effective maintenance measures/treatments. It was concluded that PCI serves as warning system for early identification or projection of major repairs required. Also, they concluded that PCI is a function of the type of distress, density of distress and severity of distress.

Since geographical information systems with their spatial analysis capabilities, match the geographical nature of the road networks, they are considered the most appropriate tools to enhance pavement management operations, with features such as graphical display of pavement condition (Elhadi, 2009).

2.1 Micro PAVER Software

PAVER inventory management is based on a hierarchical structure composed of networks, branches, and sections, with the section being the smallest managed unit. This structure allows users to easily organize their inventory while providing numerous fields and levels for storing pavement data. It is a decision making tool for the development of cost effective maintenance and repair alternatives for roads and streets, parking lots, and airfields. PAVER provides many important capabilities (Norlela, *et al*., 2009; U.S Army Corps of Engineers, 2011).

2.2 Pavement Inventory

The pavement inventory is defined in terms of network, branch, and section. A pavement section is the smallest management unit for considering a major maintenance and repair (M&R) project. Key features to be considered in section definition are pavement type, structure, construction history, functional classification (or traffic), and existing condition (Shahin, 2005).

3. Methodology

3.1 Case study

Al-Kut is the capital city of Wasit governorate in the middle part of Iraq. The geographical coordinates of this governorate are (44°32`- 46°36`) longitude and (31°57`- 33°25`) latitude. Ten roads (8 internal and 2 external) in this city were chosen to survey for PCI calculations. These roads represent different kinds (primary, secondary, and collector), different types of areas (urban and rural area); different population (highly and lowly populated area). The information of these roads present in Table (1).

3.2 Database System

The ArcView 9.3 is a full-featured Geographic Information System (GIS) software for visualizing, managing, creating, and analyzing geographic data. In order to digitize accuracy features, it was needed import satellite images that provide ability to be the spatial reference, which matches with GPS's coordinates. GPS was used to collect the coordinates of the centerline and starts and ends of the road. Polyline tool was used to draw the roads in the study area with their information as shown in Figure (1).

Table 1: Information of the Case Study

Case No.	Street name	Length(m)	Width (m)	Type	No. of lanes	Geometric type
1	Al-Kafaat	1334	7 for one side	Divided	4	urban
2	Al-Naseej	1486	11.25 for one side	Divided	6	urban
3	Al-Amarah	1700	7 for one side	Divided	4	urban
4	Al-Sada	575	11.25 for both sides	Un divided	4	urban
5	Al-Masbeh	3463	15 for both sides	Un divided	4	urban
6	Al-Maymoon	2920	9 for one side	Divided	4	urban
7	Al-Zahraa	726	6.5 for one side	Divided	4	urban
8	Al-Taameem	1534	6 for one side	Divided	4	urban
9	Kut-Baghdad	3500	7 for one side	Divided	4	rural
10	Kut-Badra	3500	7 for both sides	Un divided	2	rural

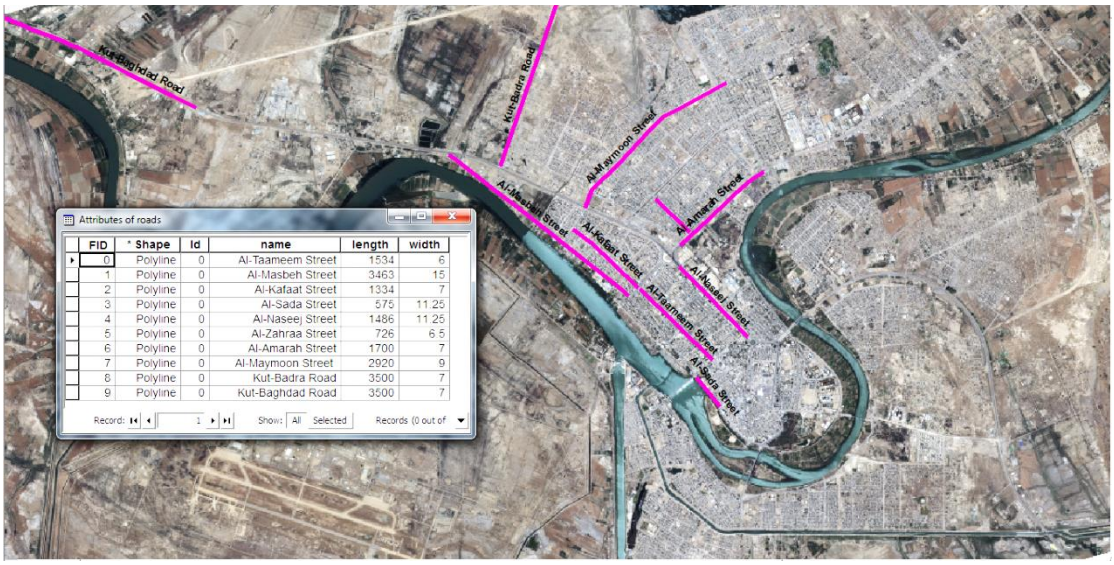

Figure 1: Satellite Image for the Case Study

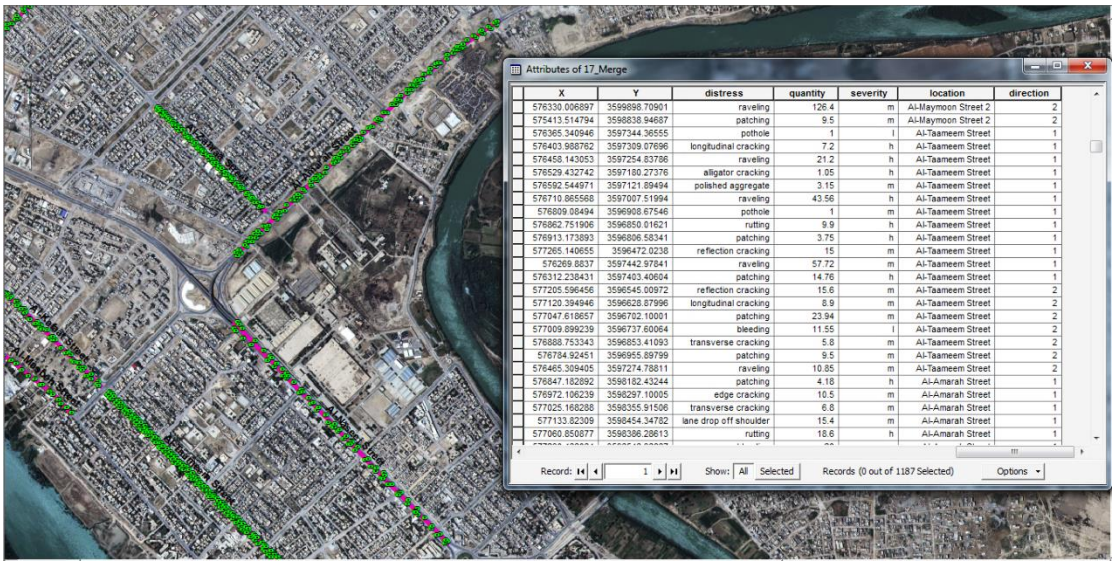

Figure 2: The Distresses in the Case Study with their Information

3.3 Condition Survey

Condition survey is an attempt to provide a comprehensive assessment of the reliability or acceptability of highway pavement sections and it is very valuable when determining priorities for maintenance funding within a major road system. In this research through using the camera, Hand Odometer Wheel, tape, straight edge and data sheet, it was recorded a complete information about each distress point such as distress type, severity, amount, location, and coordinates and saved as a database in GIS program as shown in Figure (2) above.

3.4 PCI Calculations

The following steps are needed for PCI calculations: - (as mentioned in Shahin, 2005).

1) Determine the total number of the sample units in the pavement section (N) by dividing the section area by the sample unit area which is (225±90 m^2),
2) Determine the minimum number of sample units (n) that must be surveyed to obtain an adequate estimate of the section's PCI. Equation (1) was used to obtain (n)

$$n = \frac{Ns^2}{\{(e^2/4)(N-1)+s^2\}} \quad (1)$$

3) Determine the sampling interval (i) by dividing the total number of the sample unit (N) by the minimum number of the sample units (n).

Where:

N= total number of sample units in the pavement section

e =allowable error in the estimate of the section PCI (*e* was equal to 5)
s= standard deviation of the PCI between sample units in the section (s=10 was used; initially inspected).

3.5 Preparation of Micro PAVER's Input data

To assess pavement condition, PAVER system has capability to perform pavement condition analysis, the desired network/branch/section must be verified and inspection information of the pavement sections has been entered to estimate pavement condition index. The PAVER system classifies pavement network to branches and sections prior to perform condition analysis, as inventory button provides tools to view, edit, and define pavement networks.

4. Analysis of Results

4.1 Condition Inventory

The complete surveying was done to the case study. Table (2) represents the distresses that have been found with their quantities in different severities. It can be seen that the raveling is the most common and repeated distress type in the study area.

Table 2: Distresses in the Study Area with their Quantities

Distress type	Unit	Low Severity	Medium Severity	High Severity
Alligator Cracks	m^2	791.97	1542.78	686.42
Block Cracks	m^2	241.33	1446.46	62.73
Transverse Cracks	m	263.63	1008.77	222.4
Longitudinal Cracks	m	212.8	1659	533.3
Reflection Cracks	m	30	129.6	0
Edge Cracks	m	248.95	556.66	17.2
Rutting	m^2	243.17	346.55	32.72
Bleeding	m^2	109.6	226.74	45.74
Bumps & Sags	m	12.5	10	0
Corrugation	m^2	14.1	57.12	3.36
Depression	m^2	63.6	127.15	38.26
Lane/shoulder drop off	m	267.5	377.8	35.6
Pothole	count	32	54	29
Patching	m^2	270.26	343.87	116.16
Raveling	m^2	1666.81	2979.01	333.74
Polished aggregate	m^2	214.79		

Table 3: Information of each Section in the Study Area for PCI Calculation

Study area	Direction	Section area	Sample unit area	N	n	i	No. of inspected units
Al-Naseej Street	side 1	16717.5	315	53	12.5	4	14
Al-Naseej Street	side 2	16717.5	315	53	12.5	4	14
Al-Kafaat Street	side 1	9338	231	40.4	11.7	3	14
Al-Kafaat Street	side 2	9338	231	40.4	11.7	3	14
Al-Sada Street	both sides	6468.75	225	28.8	10.5	2	14
Al-Zahraa Street	side 1	4719	221	21.4	9.4	2	11
Al-Zahraa Street	side 2	4719	221	21.4	9.4	2	11
Al-Amarah Street	side 1	11900	231	51.5	12.4	4	13
Al-Amarah Street	side 2	11900	231	51.5	12.4	4	13
Al-Maymoon Street	side 1	26280	288	91.3	13.7	6	16
Al-Maymoon Street	side 2	26280	288	91.3	13.7	6	16
Al-Taameem Street	side 1	9204	228	40.4	11.7	3	14
Al-Taameem Street	side 2	9204	228	40.4	11.7	3	14
Al-Masbeh Street	both sides	51945	300	173.2	14.7	11	16
Kut-Badra Road	both sides	24500	224	109.4	14.1	7	16
Kut-Baghdad Road	side 1	24500	224	109.4	14.1	7	16
Kut-Baghdad Road	side 2	24500	224	109.4	14.1	7	16

4.2 PCI Determination

Each road in the study area is divided into sections and sample units as mentioned in (Shahin, 2005) and the information for calculation of PCI are presented in Table (3).

After input each point of distress type that found in the study area with the information of Table (3) for each road, in the Micro PAVER program, it is give the PCI value directly corresponding to the condition rate, which is poor, fair or good. PCI provides an objective and rational basis for determining maintenance and

repair needs and priorities. The results of PCI values are shown in Figure (3).

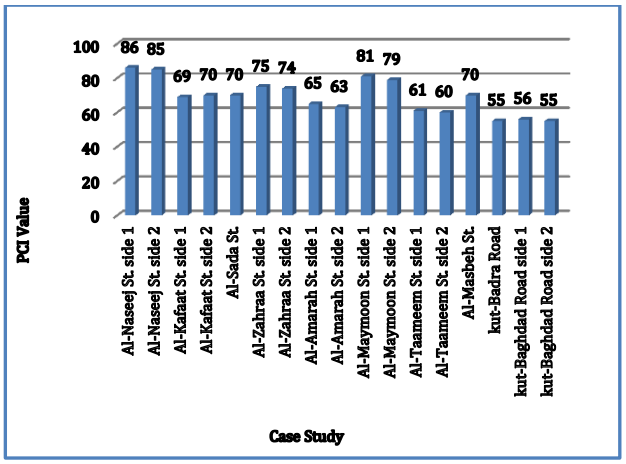

Figure 3: PCI Value for Each Road in Case Study

It appears that the lowest value of PCI is 55, which means poor condition for Kut-Badra and Kut-Baghdad. Both roads are external and suffering from the passage of heavy loaded traffic vehicles and lack to routine maintenance. While the highest PCI is 86 and 85 for Side1 and 2 of Al-Naseej Street respectively. This road is internal and is rehabilitated a short time ago, so the distresses are little.

4.3 PCI Condition Rating Categories

From Micro PAVER software results, Figure (4) displays the condition percent of all sections in study area. Based on PCI custom rating which is classified the condition into three categories: good, fair, poor; 117 sections in all roads in case study which represent (48%) are good, while 61 and 65 sections which represent (25 and 27 %) are in fair and poor condition. Figures (5 a to c) manifest the condition of sections in each road in case study. It was noticed that Al-Naseej Side1 (100%) good condition that means all section in this road in a good state while the sections in Kut-Badra with (50%) in fair and poor condition.

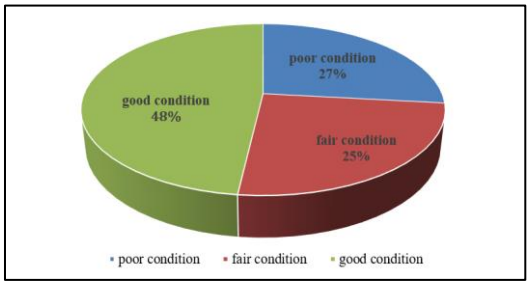

Figure 4: PCI percentage for all Sections in Case Study

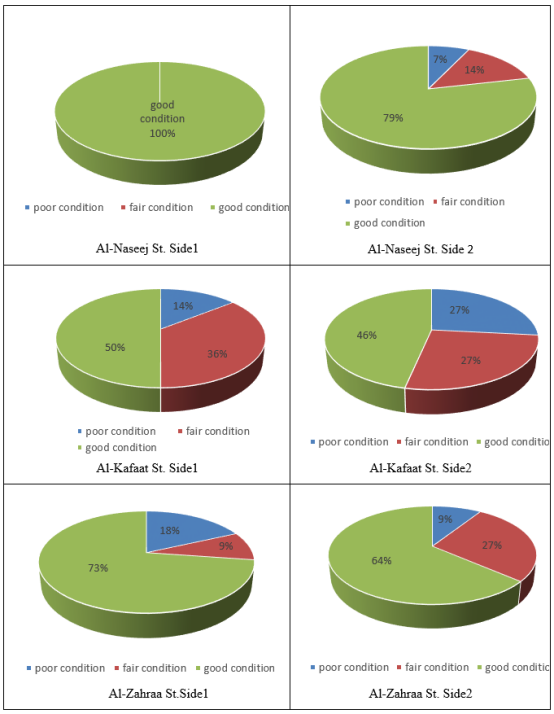

Figure 5 (a): PCI percentage for Sections in each Case Study

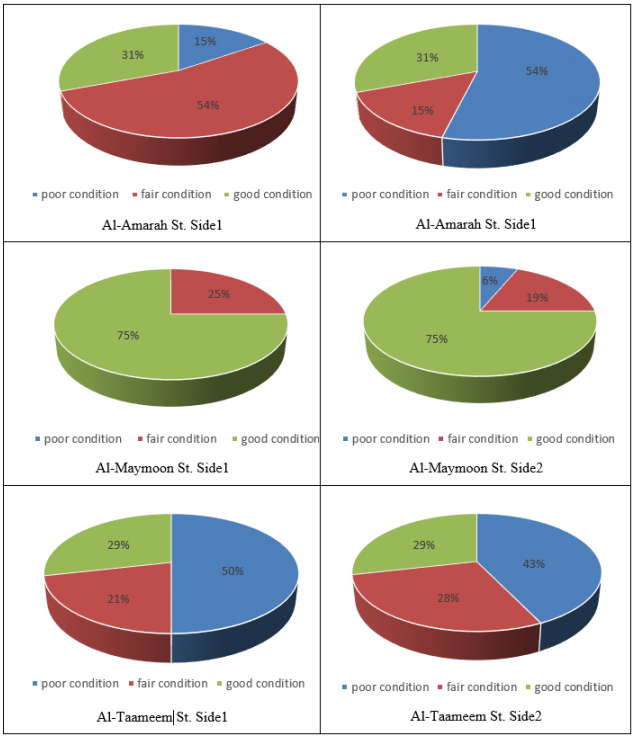

Figure 5(b): PCI percentage for Sections in each Case Study

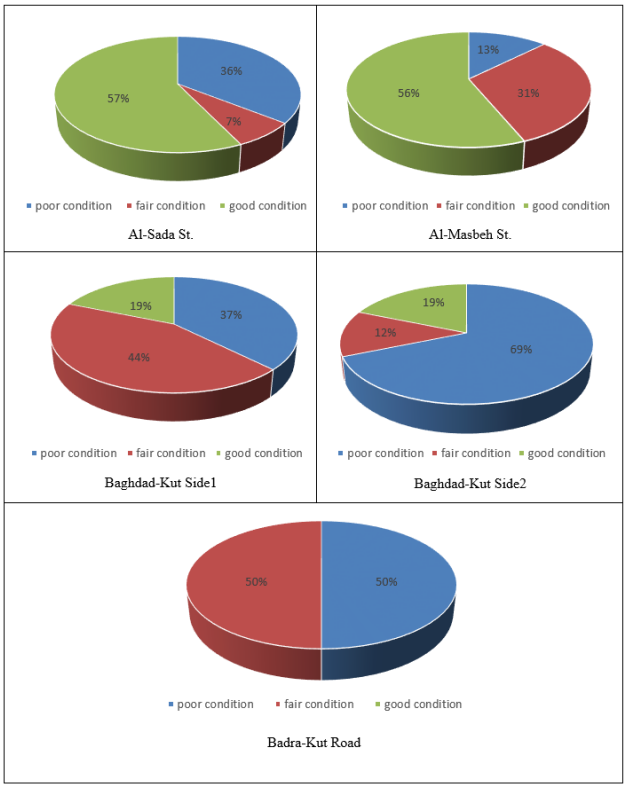

Figure 5 (c): PCI percentage for Sections in each Case Study

Conclusions

From the evaluations the PCI, the following conclusions can be drawn:

1) Micro PAVER 5.2 software has a good ability and more accurate to estimate pavement condition index (PCI) to decrease expected errors related to conventional method (hand calculations).
2) This study is the first time to calculate the PCI for roads of Al-Kut city that have not been surveyed before. Therefore, it is important to create an annual road deteriorations database system and

the resulting change in the PCI values which occurs every year.

3) Using GIS software as a database for identifying the location of each distress point with complete information during the surveying, and update it continuously, that will help in maintenance decision and continuous monitoring of the PCI is necessary to establish the rate of pavement deterioration, which permits early identification of major rehabilitation needs.
4) According to Micro PAVER results; there are 117 sections of roads which represent 48% of the study area are in good condition while 61 and 65 sections which represent 25 % and 27 % are in fair and poor condition respectively.

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