Assessment of Al-Amarah street within the Al-kut city using pavement condition index (PCI) and GIS technique

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Abstract. The capabilities of geographical system and their spatial analysis is considered the most appropriate tools to enhance pavement management operations, with features such as graphical display of pavement condition. In Iraq, most of transportation agencies do not have a tool that is used as a database for road deteriorations, so there is a need for road surveying and storing the collected information in GIS to know the condition of every road with details. Furthermore, these data can be used for maintenance process and estimation of prior cost. This research has been carried out to estimate of flexible pavement condition through visual surveys using the Pavement Condition Index (PCI) method; so it can provide an easy way to calculate the PCI based on GIS data with Micro PAVER software 5.2. Al-Amarah Street, which is internal road in Al-Kut city in the eastern part of Iraq, is used as a case study. The average pavement condition index of the selected case study is found to be “64” using Micro PAVER 5.2 software which mean “Fair” pavement condition. Arc Map 9.3 has been applied in this study to make an integrated maintenance system for each road in the region demonstrating the annual road deteriorations and the resulting change in the PCI values which occurs every year. The study provides an easy and simplified way of presentation the details of deteriorations on the satellite or the geographical map of the road in which each type of distress has been symbolized with specific sign and each PCI value has been represented with specific color.

1 Objective of the research

The aim of this research is to produce a thematic map for distress types in the city network with their completely information about severity, quantity, (x,y) coordinates for each distress type. Taking advantage of the ability of GIS tools to store the data and display it in any time needed; it is useful to use GIS as a database to make a decision for maintenance and then to achieve best results at lowest possible costs.

In this research, visual surveys are used to determine the Pavement Condition Index (PCI) of the selected roads according to ASTM D6433-07, 2016 [1].

Many road institutions in Iraq suffer from lack in road documentation and do not have a database program for storing; this reflects a poor system of maintenance. Therefore, the use of GIS software can effectively solve that.

2 Background

The functions of highway facilities are to provide travel quickly, safely, and comfortably. The lack of any of these characteristics indicates functional deficiencies therefore; the causes of the functional deficiency are

measured to assess the pavement performance properly (Yoder, and Witczak, 1975) [2].

Evaluation of surface distress is the one that has historically been characterized by a lack of uniformity in data collection practices, since there are currently no standards accepted by the entire transportation community (Haas et al., 1994; Flintsch and McGhee, 2009) [3 and 4].

As distress increases in amount and severity, roughness, and safety hazards increase (Metal, 1980) [5]. Deterioration is a result of complex distress as pavement cracking through fatigue under repeated loadings and environmental cycles (Gary et al., 2009) [6].

To simplify the collection of distresses data, Geographic Information System (GIS) and remote sensing through Global Positioning System (GPS) are proposed by Salih (2006) [7], to be used together with a large amount of quantitative and qualitative information regarding pavement management. A PCI model through using a stepwise regression technique was developed to predict pavement condition for local flexible pavement.

In the recent past (GIS) has acquired tremendous importance in various applications; for transportation planning (GIS) is implemented to solve transportation problems (Didigwu, 2010) [8].

Ibraheem and Falih (2012) [9] pointed out to use GIS as tool for the pavement management decision making. A

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GIS based system was built, which provides information that can be used as a platform for all aspects of the Pavement Maintenance and Management System (PMMS) process. 23 sections were selected that distressed with PSI element to draw a map that connected between roadway and their values of PSI. The range of PSI for these sections was low and they suggested a treatment for each section based on the types of distresses and PSI value.

One of most modern programs in geographic information systems is ArcGIS 9.3 which is one of the families of geographic information systems that have contributed to the completion of the GIS (Liu et al., 2010) [10].

To assess pavement condition, PAVER system used by Mohamed, (2015) [11] to perform pavement condition analysis for Section R4 that is a segment from Expressway No. 1 which connects between Hilla and Baghdad city in the middle of Iraq. The PCI factor was used with other measure to estimate the main performance indicators affecting asphalt pavement maintenance alternatives.

ASTM D6433-07 (2016) [1] provides a manner to establish Pavement Condition Index (PCI) in order to state the service level for flexible and rigid roads.

2.1 Pavement condition survey

One of the most important functions of pavement engineering is that dealing with evaluation of in-service pavement. 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) [2]. It will serve several purposes including, establishing need for including design requirements of procedures, and pointing out special conditions influencing overlay design (Finn and Monismith, 1984) [12]. The PCI is a quick method of comparing the overall condition of pavement and magnitude of rehabilitation needs. Figure (1) shows how pavement condition typically deteriorates over time Johnson, 2000) [13].

2.2 Micro PAVER program

Micro PAVER is developed to provide engineers with a systematic approach for determining maintenance and rehabilitation needs and priorities for pavement management (Shahin and Walther, 1990) [14]. Micro PAVER is used to manage roads, streets, parking lots, and airfield pavement. The PAVER system is based on the Pavement Condition Index (PCI) survey and rating procedure (Norlela, et al., 2009) [15].

PAVER for Windows is an automated pavement management system (PMS). 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 (U.S Army Corps of Engineers, 2011) [16].

Fig. 1. Performance of preventive Maintenance treatments.

3 Methodology

3.1 Case study

Al-Amarah Street is a collector road in Al-Kut city that is located in the eastern part of Iraq as shown in Figure (2). This road collects from most minor streets in the city. It extends from the entire part to the end of Al-Kut city toward Al-Amarah city. It is a divided multilane with two lanes in each direction. The lane width is 3.5 m with a median of 1 m width. Many heavy vehicles use it toward Al-Amarah city, which in turn leads to deterioration of this road most of the time.

3.2 Map digitizing

The ArcView9.3 is full-featured Geographic Information System (GIS) software for visualizing, managing, creating, and analyzing geographic data (Halder, 2012) [17]. Through the inspection survey, the GPS (Global Positioning System) type of (GEO-XT) was used to identify the location of each distress point in the road as shown in Figure (3).

Fig.2. Location of Al-Amarah Street.

Fig. 3. Database of distresses shape file.

Depending on coordinates from GPS, each distress point must be entered in the GIS Software with its type, severity, quantity and location; in which these details about deformation are required to be used as a database. For more readily, the type of distress can be classified as shown in Figure (4) based on the symbol types in the legend of the map. For example, a sign of red triangle refers to alligator distress and a circle with red color refers to corrugation. Through activated Hyperlink bottom in GIS Arc Map a feature of each distress point can be also displayed as presented in Figure (5). The features with the input data can integrate information about each deformation in the road.

Fig. 4. Distress types in Al-Amarah Street.

Fig. 5. Connect digital image to failure exist in the roads using hyperlink.

3.3 PCI calculation

The following steps are needed for PCI calculation: - (Shahin, 2005) [18]

- 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 $(225 \pm 90 \text{ m}^2)$,
- 2- Determine the minimum number of sample units (n) that must be examined in order to estimate the PCI value for the selected road section. Equation (1) was used to obtain (n)

$$n = N \cdot s^2 / [(e^2/4)(N-1) + s^2] \quad (1)$$

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).

3.4 Calculations for the case study

The length of Al-Amarah Street is 1700m and 7m width, the area of the section is 11900 m^2 ;
 $N = 11900/231 = 51.5$ (total sample unit).

Using Eq. (1); $n = 12.4$ (minimum number of sample units to be surveyed)

$i = N/n = 4.15 \approx 4$ (as mentioned in Shahin, 2005 [18]).

Length of sample unit to be surveyed = $\frac{231}{7} = 33 \text{ m}$

That means that the sample units to be surveyed and entered in PAVER are 1, 5, 9, 13... 49.

The dividing process of the section into sample units is conducted using GIS Arc Map as shown in Figures (6) and (7). The selected sample units are with blue color as shown in Figure (7) with their lengths, widths and area of each inspected units. The points of distresses in each selected sample unit are entered in Micro PAVER software with their information as saved in GIS program and presented in Figure (8).

Each side of direction in the road is calculated and entered in Micro PAVER independently.

Fig. 6. Sample units of Al-Amarah Street.

As shown in Figure (8), different types of distresses are found in the road. The letter (l) refers to (low severity), (m) refers to (medium severity) and (h) refers to (high severity). The detection level of severity of each distress that found in the case study relied on ASTM D6433-07, 2016 [1].

4 Analysis of results

4.1 PCI determination

After entering each distress point in each sample unit, Micro PAVER program gives the PCI value directly as shown in Figure (9) and (10). These figures illustrated that the pavement condition index is 65 and 63 for side 1 and side 2 respectively. This means that the condition of the road is fair as mentioned in ASTM D6433-07 (2016)

[1] and shown in Figure (11), also the program indicates the fairness condition.

The case study is within the critical PCI (Mohamed, 2015) [11] that is defined as the PCI value at which the rate of PCI loss increases with time or the cost of applying localized preventive maintenance increases significantly. The typical critical PCI is ranging in between 55 to 70.

Fig. 7. Information of sample units of Al-Amarah Street.

Fig. 8. The points of distresses in each selected sample unit as entered in Micro PAVER software

Fig. 9. Automated PCI calculation from the Micro PAVER System for Al-Amarah Street, side 1.

Fig. 10. Automated PCI calculation from the Micro PAVER system for Al-Amarah Street, side2.

entered in GIS Arc Map program with their values of PCI for both sides for Al-Amarah Street.

Table 1. Condition indices for Al-Amarah Street, side1 &2.

Sample No.	Sample Type	Sample Size	Units	PCI-Side1	PCI-Side 2
1	Random	231	m ²	75	54
2	Random	231	m ²	57	85
3	Random	231	m ²	77	65
4	Random	231	m ²	69	49
5	Random	231	m ²	81	71
6	Random	231	m ²	60	75
7	Random	231	m ²	56	55
8	Random	231	m ²	57	62
9	Random	231	m ²	74	55
10	Random	231	m ²	69	55
11	Random	231	m ²	53	53
12	Random	231	m ²	53	80
13	Random	231	m ²	70	53

Fig. 11. Pavement Condition Index (PCI), rating scale, and suggested colors (ASTM D6433-07, 2016).

Micro PAVER also displays the condition of each sample unit as presented in Table 1.

Figure (12) and (13) presents PCI value for each sample unit, in which it can be noticed that the highest PCI value is 81 and 85 for Side 1 and 2 respectively, while the lowest value for PCI is 53 in Side1 and 49 in Side2. Figure (14) and (15) shows the sample units that

Fig. 12. PCI value for each sample units in Al-Amarah St. Side1.

Fig. 13. PCI Value for each sample Unit in Al-Amarah st., side2.

Fig. 14. Sample units for side 1 with their PCI values.

Fig. 15. Sample units for Side 2 with their PCI values.

Depending on PCI value, classifying each sample unit with specific color is based on ASTM D6433-07, 2016 [1] as presented in Figure (11).

Figures (16) and (17) show that each sample unit has its own color, based on the color in the legend of the map, in which the difference in color represents the range of PCI value. For example the PCI value between (0-10) is symbolized with gray color which indicates that there are many distresses or high distress intensity within the assessed section, while (86-100) is symbolized with dark green color which in turn indicates that the selected section is with low distresses or low distress intensity.

Fig. 16. PCI value scale of sample units for side 1 in Al-Amarah St.

Fig. 17. PCI value scale of sample units for side2 in Al-Amarah St.

The total value of PCI for both sides of the road is presented in Figures (9) and (10). The values are 65 and 63 which is located within the range of yellow color region as shown in Figure (18).

Fig. 18. Total PCI value for side 1 and 2.

5 Conclusions

Based on the assessment of results, the following conclusions are drawn

- 1- To avoid expected errors related to conventional method (hand calculation), pavement condition index (PCI) has been estimated using Micro PAVER 5.2 software. The average pavement condition index of the selected case study is found to be “64” which mean “Fair” pavement condition and critical PCI.
- 2- Arc Map 9.3 has been applied in this study to a road in a region that has not been surveyed before. Therefore, it is essential to make an integrated maintenance system for each road in the region demonstrating the annual road deteriorations and the resulting change in the PCI values which occurs every year.
- 3- The study provides an easy and simplified way of presentation the details of deteriorations on the satellite or the geographical map of the road in which each type of distresses has been symbolized with specific sign and each PCI value has been represented with specific color.
- 4- It is a good way to use the PCI value of road sections for road maintenance prioritization because the adopted methodology depends on the visual condition survey and the calculation of this index depends on direct measurements of each distress of pavement not on just visual rating.

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