Using PAVER Software to Evaluate Pavement Condition Index of Highway Segment in the North Sector of Najaf City (Case Study)

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Abstract. Current paper present part of comprehensive case study for urban highway networks of north sector of Najaf city located 161 km Southwest of Baghdad the capital of Iraq. The main goals of current paper are to evaluation pavement condition index denoted as (PCI). Values of PCI acting a main factor on depending maintenance of pavement, selecting economic alternative, increasing development of engineers and technician’s capabilities, in order to reach the best maintenance management process and achieve the best riding level with lowest costs and the shortest travel time. PAVER software uses surveying data to calculate pavement condition index which should be within rating from zero, which mean pavement in failed condition, to 100, that mean excellent pavement condition. Pavement's condition is providing predicting its maintenance and Rehabilitation requirements. Free issue of PAVER 5.2 software was used to calculate values of PCI for a minor arterial urban highway in north sector of Najaf city, that is the Najaf-Karbala highway located from Al-Askarain Tunnel intersection to the end of Al-Nidaa district, with length (8011m). Manual geometric and types of distresses survey was depended instead of using assessment technologies to consider the type, degree of severity, of distresses for sample unites along the highway. As a results of implementing PAVER 5.2 software depending on field survey data collection, PCI value is equal to 80. That’s mean this part of the selected study section was in good situation.

Keywords: Pavement maintenance Management System (PMMS), PAVER 5.2, flexible pavement, pavement condition index (PCI).

1. Introduction:

Each activity aimed to improve pavement structure performance and made any pavement segment in acceptable level of service represented as Highway maintenance. Highway maintenance should give a respectable contribution between environmental condition and transportation requirements. The growing number of traffic load, increasing road mileage, increasing commercial vehicles weight, needs for advanced specifications for maintenance and performance illustrate the main factors controlling the need for maintenance and rehabilitation, (Almuhanna, et al, 2018).
Road construction projects are always costly, especially if implemented with high quality standards. In order to achieve the functional purpose for which it was established for the best and long design life, a scientific program for maintenance work must be provided by the competent authorities.

It is an inaccuracy to follow traditional survey methods, which rely on the visual scanning of the engineer and his cumulative experience as this method offers a wide range of personal explanations and a variety of opinions which gives an unclear picture to make the right decision to perform the necessary maintenance of the road. Pavement management system (PMS) contain many engineering activities related to pavement design, construction, and maintenance. Figure 1, shows Pavement maintenance management systems (PMMS). Pavement maintenance operations represent an effective approach in process strategies and fund resource keeping (R Haas et al, 1994). Evaluate current pavement condition, forecast future conditions, analysis process of alternatives, in addition to select proper rehabilitation strategy represent consequent PMMS process stages for any given pavement section, (Garber& Hoel, 2008).

Typically, pavement condition index (PCI) is pavement rating system employs by PMMS as the source of assessment of present and expected pavement performance. Figure 2 demonstrate traditional curve characterizes pavement’s expected performance relationship with pavement life in years. Usually, future performance prediction can be obtained from this curve. The estimated pavement condition after time period, multiple economical approach and maintenance methodologies can be done according to optimum cost effective maintenance treatment, (TRB, 2005).

In other words, (PMS) is all analytical tools and methods that contribute to finding the best strategies for maintenance usable berths over a specified period time. Maintenance strategies include all set of different activities identified for each highway system to upgrade the pavement classification to a higher level than the minimum requirement (LU& Lyton, 1976).

Highways in north sector of Najaf city (as all the city highways network) suffers from bad management or lack of using such system in order to put the priority of maintenance process and selecting the best alternatives for its road network. Although extensive research has been carried out on specific cities in Iraq, no such single study exists which deals with evaluation pavement condition in north sector of Najaf city. Therefore, the aim of the present study is to shed light on the type of distress spreading in part of selecting study area and to evaluate Pavement Condition Index (PCI) using PAVER 5.2 software. Pavement Maintenance Management System that illustrated in PAVER software, initially was established in the late 1970s to help in the pavements maintenance and rehabilitation process.

**Figure 1.** PMMS as a components of PMS (Garber& Hoel, 2008), (Abo-Hashema et al, 2006).
AASHTO has identified the maintenance, rehabilitation and reconstruction strategies of the pavement as follows (AASHTO, 1997):

- Routine maintenance: The application of daily activities includes maintenance by cadres to control all defects in early times and maintain the functional status of the road. Examples of such activities are drill trenching and filling or sealing cracks.

- Rehabilitation of the pavement: It is divided in to two part.
  - Simple rehabilitation is intended to maintain the current pavement.
  - The main rehabilitation involves improving the durability of the pavement by increasing the thickness of the pavement and as a result, highway service life extended.

- Reconstruction of the pier: This option is used when the functional performance of the road is no longer available. Requiring the removal of the current pavement structure and replacing it with the equivalent structure.

2. Distress of flexible pavement;

According to many references, failures in pavement take two essential different types. these failures are, (Yoder& Witczak, 1976):

- Functional distress: the functional distress all that disturbed pavement surface and caused decrease in comfort for drivers in vehicle along the highway,

- Structural distress: any breakdown or collapse in structure components of pavement in one layer or more, and come to be in un capable to transmit load passes over its surface. functional distress always couples/ or not with structural distress. While, structural distress always accompanied with flailer in pavement surface (functional distress).

Hot mix asphalt pavement represent the high percent of highways constructed in Iraq, as usual in Najaf city. Hence, in this paper, distresses in flexible pavement types had been proposed. Flexible pavement distress evaluated by occasion preservation treatments. It well known, the procedure of pavement distresses evaluation has been known in term of inspection survey (LTPP, 2003). Weak of structural capacity, using low material quality, insufficient design, bad construction techniques in addition (or not) absence of preventive maintenance process are represent key factors or a grouping of factors affected Pavement distress. PAVER 5.2 software categorize 5 major classes in hot mix asphalt pavement surface distresses (Miller& Bellinger, 2003). These categories are:

A- Pavement cracking such as "alligator cracking or known as fatigue cracking, longitudinal and transverse cracking, block cracking, slippage cracking, joint reflective cracking, and edge cracking".

![Image of Figure 2](image-url)
B- Surface Deformation take one form of "rutting, corrugations, shoving, depressions, swell, bumps and sags."

C- Disintegration defects which take place from surface to the lower layers such as "potholes, patching and utility cut patching."

D- Surface defects like effect of "weathering and raveling, bleeding, polishing."

E- Miscellaneous distresses which take different forms such as "lane/shoulder drop off, railroad crossing."

Below, table 1 shows flexible pavement distress groups.

**Table 1** PAVER 5.2 Classification Distress for Asphalt Pavements According to its help file (Shahin & Smith-2005, Yoder & Witczak-1976, Miller & Bellinger-2003, Almuhanna, et al-2018, PAVER5.2 helps index).

| Code | Distress                  | Measure Unit | Defined Severity Levels? | Type of Distress         | Main Cause      |
|------|---------------------------|--------------|--------------------------|--------------------------|-----------------|
| 1    | Alligator Cracking        | m²           | yes                      | Structural               | Load            |
| 2    | Bleeding                  | m²           | yes                      | Functional               | Other           |
| 3    | Block Cracking            | m²           | yes                      | Structural               | Climate         |
| 4    | Bumps And Sags            | m²           | yes                      | Structural & Functional  | Other           |
| 5    | Corrugation               | m²           | yes                      | Functional               | Other           |
| 6    | Depression                | m²           | yes                      | Functional               | Other           |
| 7    | Edge Cracking             | m²           | yes                      | Functional               | Load            |
| 8    | Joint Reflection          | m²           | yes                      | Structural               | Climate         |
| 9    | Lane/Shoulder Drop-Off    | m²           | yes                      | Functional               | Other           |
| 10   | Longitudinal And Transverse Cracking | m² | yes | Structural               | Climate         |
| 11   | Patching And Utility Cut Patching | m² | yes | Structural & Functional | Other           |
| 12   | Polished Aggregate        | m²           | no                       | Functional               | Other           |
| 13   | Potholes                  | Number       | yes                      | Structural & Functional  | Load            |
| 14   | Railroad Crossings        | m²           | yes                      | Functional               | Other           |
| 15   | Rutting                   | m²           | yes                      | Functional               | Load            |
| 16   | Shoving                   | m²           | yes                      | Functional               | Load            |
| 17   | Slippage Cracking         | m²           | yes                      | Structural               | Other           |
| 18   | Swell                     | m²           | yes                      | Functional               | Other           |
| 19   | Weathering And Raveling   | m²           | yes                      | Functional               | Climate         |
3. Selected Study Area Description

As shown in Figure 3, the selected highway section represents part of north sector of Najaf city, located in AL-Najaf governorate located 161 km Southwest of Baghdad the capital of Iraq. Name of section was Najaf-Karbala highway, extended from Tunnel intersection Al-Askarin to Al-Nidaa district. Length of selected highway section was (8011m). Geometric design of selected section was two-way divided highway with three lanes in each direction have total width of (10.5 m) and two side walk of 2.0 meter, width of median was (3 m).

4. PAVER 5.2 Software Program:

The pavement condition as mentioned earlier, is usually assessed by (PCI). The system developed by United States Army groups of engineers and approved by several associations such as the American Public Works Association (APWA) and the American Society for Testing and Materials (ASTM). According to PAVER5.2, PCI ranging from 0 to 100 as issued in Illinois center for Transportation research report (APWA, 2012). Currently, the PAVER 5.2 software and its new versions are widely using by at least 600 cities, countries, corporations, private foundations and airport, (Obead, 2012). PAVER represents only standard (ASTM) certified platform standard in (ASTM, 1999B) standards. The PAVER software is interesting and providing user support. Positive feedback on program performance was one of the most important elements that helped (PMS) modify and improve the program (APWA, 2012).

Selected road divided to suitable numbers of segments. These segment parts are defined boundaries within which pavement components in terms of geometrical and functional properties. According to PAVER 5.2, highway section divided into sample units, each segment should have an area approximately 2500 ± 1000 sqf define a asphalt surfaced sample unit of roads, (Shahin& Smith, 2005). The collected data needed for calculating Pavement Condition Index including:

1. Distress in terms of category, severity, and density, in addition to other data of section type, location, and extension (Obaidat& Al-kheder, 2006),
2. Roadway Geometry and types if “arterial, collector or local”, details of road if its divided with median or non-divided, title name, segment length (m), highway width (m), and directional classification (one or two-way).

PAVER 5.2 recommended a methodology depend on inspection survey data results to find PCI:

1. Types of distresses found in Surface of segment unit boundary which should be measured in terms of total area, segment length or width and evaluation process depend on these distresses type, frequency and severity, (ASTM, 2011), (ERDC-CERL, 2009).
2. A photograph for each type of sample distresses with different severity in section of roadway necessary to evaluate the pavement condition index.

According to PAVER 5.2 Pavement condition index have rating as guide shows present condition of pavement as compared to standard PCI uses a scale of 7 different kinds started from excellent, to good, to satisfactory...etc. until reach to failed; on the other hand, there is a specific version of PCI scale depend on 3 classes. These are good, fair, and poor, in order to easy discrimination of these categories, they take different colors assigned by PAVER 5.2 software as shown in Figure 4 (Shahin& Smith, 2005).
5. Field Measurements:
Field measurement in the current study area consists of distress types. Distresses shown in present study are classified into the following types below and shown in the Table 2:

1- Alligator Cracking: Also called fatigue cracking, this distress type severity is figured according to development of cracks within network. Measured by tape, in area unit($m^2$).

2- Potholes: Quantity of distress is examined by number, while severity is based on diameter and depth of the potholes.

3- Rutting: Quantity is measured in area units ($m^2$), and the severity is determined in terms of average depth of each rut.

4- Longitudinal cracking: is measured by using tape in (m, L).
5- Edge cracking: that looks like alligator cracking which is found within (0.3048) to (0.609) m, from edge of the pavement.
6- Transverse cracking: Is measured by tape in (m. L).
7- Roughness: Is caused by weathering and raveling distresses, measured by tape in area units (m$^2$).

Table 2 types of flexible pavements distresses listed in the study from data collection survey

| No. | Distress type       | Photo taken from studied section |
|-----|---------------------|---------------------------------|
| 1-  | Alligator Cracking  | ![Alligator Cracking](image)    |
| 2-  | Potholes            | ![Potholes](image)              |
| 3-  | Rutting             | ![Rutting](image)               |
| 4-  | Longitudinal cracking | ![Longitudinal cracking](image) |
6. Result of Application PAVER 5.2 Software:

The PAVER 5.2 methodology is building on assessment by determining distress type, extent and severity on pavement surface condition. Hand calculations was using in estimation values of PCI for selected section of the study area. As mentioned earlier, quantity of each type distress had been measured in terms of square feet (square meters) for area, linear feet (meters) for length and depth, or number of occurrences in other wise.

First to all, the pavement section should be divided into number of segments represent sample units. Each unit should have an area within the range of $225\pm 90$ m², (Shahin, 2005). So, the study area was divided into (267) inspection units, each unit segment was 315 m² in area. Type of distress, level of severity and quantity, needed for estimate PCI value for each sample units. As mentioned earlier, PCI values of the highway sections calculated by PAVER 5.2 software procedure. Sampling procedure was beginning by calculating smallest sample units’ number that called (n). According to "Shahin& Smith, 2005 et al., (1976-84)". this number was given an estimation reasonably for the PCI mean value of the

|   |  Description   |
|---|----------------|
| 5- | Edge cracking |
| 6- | Transverse cracking |
| 7- | Roughness |
| 8- | Patching |

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unit, within ±5 point of the true mean PCI that means there is 95% confidence, to obtained correct PCI must be inspected all sample units. Equation 1 listed in ASTM D6433-07, shown below:

\[ n = \frac{(N+s^2)}{\left(\frac{e^2}{4}\right)(N-1)+s^2} \]  

(1)

n: represent whole sample units number of selected pavement section.
N: section area / sample area 
\(e\): acceptable error in estimated value of PCI (usually \(e\) equal to 5) 
\(s\): PCI value standard deviation (usually \(s\) equal to 10) 
Area of section=10.5 × 8011=84115.5 m² 
Area of sample = 315 m² 

According to all above values and by using equation 1:
\[ N=\frac{84115}{315}=267 \] (complete number of sample) 
\[ n=15 \] (smallest number of samples) 
The first sample should be chosen randomly by technique named as” systematic random” to determine spaces between sample units, the following steps should be observing (Shahin& Smith, 2005).

1- Selection sampling interval (i): Can be considered (i = N/n=17) where i is approximated smaller integer number value

2- Random star (s): random chose between sample unit No. 1 and interval sampling (i).

3- Determined sample unit as (s, s+i, s+2i, s+3i, etc.) for the designated pavement section:
Since i =17 then sample 1 could be the first sample to be inspected, then the successive samples are as 1, 1+17, 1+17*2, etc. that is mean the selected sample take the sequence of: 1, 18, 35, 52, 69, 86, 103, 120, 137, 154, 171, 188, 205, 222, and finally 239 

After input the information of all sample unite of selected section, PCI value for all tested sample units had been calculated. Calculation of PCI value relies on subtract values; weighting factors extending from 0 to 100 represent degree of every distress on pavement. It well knowing, 100 deduct value gives an indication the operational condition on pavement surface is Excellent, on the other hand, a value of zero indicates very poor (Shahin& Smith, 2005). Through data entry and processing by PAVER 5.2 software, calculated PCI value of selected highway was found to be equal to 80. Therefor the pavement condition is Good conferring to evaluation of highway surface distress type, density and severity.

PAVER 5.2 allows the pavement manager to select suitable process for maintenance and rehabilitation for any highways sections depend upon regular of calculated PCI value, and then priorities of field processing become easy to decided. Concerning maintenance action for studied sections need preventive maintenance such as crack sealing and patching. It well knowing that the preventive maintenance always necessary for keep the pavement condition in good quality, and stop progressing the distresses to moderate or high severity. Preventive Maintenance applies lower-cost treatments to retard a road’s deterioration, maintain or improve the functional condition, and extend the pavement service life.

7. Conclusions
Based on the outcomes of the present study, the following conclusion were formed:

1- Most of the distress of selected section are cracks from different types.
2- The condition of the pavement was good (PCI=80).
3- Preventive maintenance is the best treatment to improve pavement condition by filling and sealing the cracks as well as using batching techniques.

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