Pavement condition index (PCI) for some highways collector selected in Najaf city implemented with PAVER software

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Abstract
Pavements are the main assets of highway infrastructure. Pavement Condition Index (PCI) is a numerical index used to describe the general condition of a pavement. This paper is another trial in monitoring and find pavement condition index (PCI) by applying PAVER software version 5.2. This work aims to evaluate (PCI) of a flexible pavement of some miner collector highways in the north sector in Najaf city divericate from both sides of Najaf- Karbala suburban main collector highway in its part away from Al- Askariin intersection towards Karbala. These highway sections are Al-Rahma, Al Hizam Al Akhdar, and Al Muearid, Al Shamalii garage highways which cover a total length approximately 11.54 km in both direction of traffic movement (diverging from Najaf-Karbala highway and return to it). Field survey data such as highway section geometric design and distresses type, dimension, and severity, were collected depending on sample size and number of samples extracted, and then entered into the PAVER program to calculate PCI. The result of PAVER shows Results approved that Al-Rahma and Al Shamalii garage highways sections are in satisfactory level, while Al Muearid highway section in (fair) and Al Hizam Al Akhdar in worst case (poor). In addition to that, reasons of these defects had been figuring out according to results obtained.

Keywords. Pavement distresses, PAVER 5.2, flexible pavement, pavement maintenance management system (PMMS), pavement condition index (PCI).

1. Introduction
Pavements are the main resources of the highway system. After a highway construction completed and began in its service life, the highway would be subject to stress due to traffic load, environmental impacts, and other factors such as design, construction, and operating condition that effect on it. So, maintaining the road and monitoring its condition is essential to keep it at the best level of service. Pavement Condition Index (PCI) is a numerical index ranges from (0-100) where 0 is the worst condition of pavement and 100 is the best condition, and it is used to evaluate the pavement condition (good, acceptable, or bad) as shown in Figure 1 and predict maintenance or repair methods to ensure that the pavement continues its service life in acceptable condition [4]. Pavement management software is a successful program to estimate PCI and to recommend when applying maintenance treatments in addition to minimizing the cost of maintenance of pavements, PAVER helps to enhance the quality of life by facilitating timely repair of damaged pavements.
Hallaq [6] developed pavement maintenance management system (PMMS) has been done in Gaza city-Palestine depending on the Micro PAVER and Geo-Media professional, this study showed that both PAVER and Geo-Media professional can be considered as good tools for enhancing management process. Obaidat [12] worked on the Integration of geographic information system and PAVER system to grant an efficient (PMMS) in Irbid city-Jordan as case study. In this research an explanation on combination between GIS and PAVER system was expected to shed the light on high technological, automated, informative, practical, and reliable systems. Obead [13] formulated maintenance alternatives rely on analytic hierarchy process (AHP) and multi-criteria (MCA) system to predict the main factors affecting maintenance alternative such as budget allocations, traffic volume, safety, pavement condition, roughness, pavement strength, and environmental effect. Asim [3] developed sustainability attentions in terms of highway geometric and performance of pavement, which can be utilized for the first time in Iraq to improve native applies in evaluation and design. Ferman [9] developed multi-objective optimization model to validate the process of multi-year decision making that is relation to Iraqi PMS. Knost [11] use a (PMS) software known as PAVER to support the maintenance decision-making process they undertake on a regular basis. PMS used the PCI values to model and predict deterioration, then predict maintenance and repair requirements, in addition to estimate future budget requirements. Ewadh et al [5] developed a pavement condition index model by using Paver 6.5.7 for flexible pavement urban road in Karbala city centre. Hussain and Al Jameel [7] investigated the type of distress and evaluated PCI at the Ibn Hayan road branch in Al-Muthanna governorate, Al-Samawa city, Al-Hussain zone. The studied section was in about 1 km in length separated by 3m median and each direction width was 7.5m. It has been shown that PAVER is efficient program for evaluation of pavement conditions and for measurement of PCI accurately and quickly if it is fed with actual data on the basis of a correct diagnosis. Al-Neami et al [2] Assessment of Al-Amarah highway within Al-Kut city by means of pavement condition index (PCI) and GIS technique. 8. Kandooh and Al-Jameel [8] evaluated the pavement condition index by used PAVER 5.2.3 program for Al Shahid Mohammed Ali Al Hassani road branch in Al-Muthanna governorate, Al- Rumaitha city, with section length about 2 km separated by 4m median for each direction of 7.5m in width, as case study. It has shown that this program helps in evaluating the condition of the pavement and selecting acceptable maintenance and can assist local decision-makers and engineers in selecting the optimum maintenance of the pavement for PMS agencies. Hasan et al (2020) developed a pavement maintenance management system of multi-lane highway in Baghdad, by using Micro Paver software. The study showed that Micro Paver was a good tool for improving the management process of Iraq pavement highways since it assists in developing and organizing inventory. Mahdi [10], calculated values of PCI for a major collector 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). As a results of field survey data collection, PCI value is equal to 80. That's mean this part of the selected study sections was in good situation. The current study (represent second stage of Mahdi [10] research) was assessing the highway pavement condition index (PCI) for selected minor collector diverging from major collector Najaf- Karbala highway. Although, it focused on analysing the data to calculate PCI by using the PAVER software 5.2.3 and suggest the appropriate maintenance. PAVER software is a pavement management system that is used to determine current PCI, and to predict future pavement condition and used to select maintenance and rehabilitation needs at the optimal time and priorities. PAVER software was established and verified over past 10 years and is currently being executed by several agencies in worldwide. This software was developed by the U.S. Army Construction [15].
2. Description of Study Area
The highway sections studied are four highway sections laying on both sides of Najaf-Karbala highway in its part beyond Al-Askariin intersection towards Karbala. Shown in figure (2) these sections are.

- Al-Rahma highway section: Al- Rahma highway section selected as part of minor collector highway consist of two lanes divided highway. It connects Al-Askariin tunnel and main entry of wadi Al-Salam cemetery, passing through AL-Rahma neighborhood. As shown in figure (3-A). The length of this section is about (1000) m, shoulders width is about (1) m laterally on both sides. Al- Rahma section intersects at an angle of 90° with main collector Najaf-Karbala highway.
- Al-Hizam Al Akhdar highway section: It is two lane divided highway classified as minor collector connects the Al Askariin tunnel and the Junction City Games. As shown in figure (3-B). The length
and width of it is (1440) m & (14) m respectively and the shoulders width are (1m) alongside and intersects at an angle 100º with the main collector.

- **Al-Muearid highway section** is a two lane divided highway also classified as minor collector. This highway section connects the Al-Shamali garage bridge through the Mohandessin district and to another cemetery entrance as shown in figure (3-C). The highway section is about (1400) m in length and (11.25) m in width and (1m) shoulder width, it intersects at an angle of (70º) with Najaf-Karbala highway.

- **Al Shamalii garage highway section**: It is a two-lane highway divided minor collector that connects the Al Shamalii garage bridges to the Salam-jameh- Wafa intersection. As shown in figure (3-D), its length is about (1930) m, the width of shoulder is (1) m and intersects at an angle of (110º) degree with Najaf-Karbala highway.

### 3. Field Measurements

In the present study, the field measurement consists of the type of distress, the quantity and the level of severity associated with distress according to the relevant standards. Distresses found in the current study are:

1. **Raveling**: The severity of distress is measured in terms of the quantity of coarse aggregate dislodged. Figure (4-A) shows the raveling area as a sample of this defect in the Al-Hizam Al Akhdar highway section.

2. **Rutting**: The quantity of this distress is measured in m² and determined the severity by the average depth of the rut in addition to percent of repetition along the section. Figure (4-B) shows the raveling area as a sample of this defect in the Al-Hizam Al Akhdar highway section.

3. **Alligator Cracking**: Quantity of this type recorded by square meters. This distress is frequently seen in all four highway sections. Figure (5-A) shows the sample of alligator crack seem in Al-Rahma highway.

4. **Transverse cracking**: The quantity of distress depends on the length of the crack and level of severity depend on the average width of this crack. It is measured manually using a linear tape measure in (m). Figure (5-B) shown the sample of Transverse crack seem in Al-Rahma highway.

5. **Longitudinal cracking**: Average width of the crack determines the quantity of crack. This type is also mostly seen in all four highway sections in high percent and severity. Figure (5-C) shown the sample of Longitudinal crack seem in Al-Rahma highway.

6. **Edge cracking**: The severity of this distress determines based on the average width while, its quantity measured via use of the tape in linear (m). Figure (5-D) shown the sample of Edge crack seem in Al-Rahma highway.

7. **Potholes**: The severity of this distress depend on the diameter and depth, quantity of pothole measured by number. Figure (5-E) shown the sample of pothole seem in Al-Rahma highway.

8. **Patching and Utility Cut Patching**: Levels of severity in this type of distress depend on ride quality of the driver while the quantity measured by squared meter by tape. Figure (5-F) shown the sample of patching seem in Al-Rahma highway.
(3-A) Al-Rahma Highway Section
(3-B) Al-Hizam Al Akhdar Highway Section
(3-C) Al-Muearid Highway Section
(3-D) Al Shamalii Garage Highway Section

**Figure 3.** Details of Current Studies Area

(4-A) Raveling
(4-B) Rutting

**Figure 4.** Sample of Distresses Shown Clearly in Al-Hizam Al Akhdar Highway Section
4. Preparing input data from field survey results:
Firstly, the pavement section divided into sample units, according to shahin [14] the area of sample unit for asphalt surface is 2500±1000 ft$^2$ (225±90 m$^2$). For all highway sections an area of sample is considering equal to 270 m$^2$. Then divided the sample area (270) m$^2$ to the width of the section to determine sample length then, determine the total number of sample units in the pavement section (N) by divided the length of section to the length sample. After that, calculated the minimum number of sample (n) by used equation (1) [14], and sampling interval calculated by $i = \frac{N}{n}$.

\[
n = \frac{N \times S^2}{(e^2/4) \times (N - 1) + S^2} \quad \text{....Eq. (1)}
\]

Where:
N: is the total number of sample units in pavement section.
e: allowable error in the estimate PCI (usually, used e= 5 [14]).
s: standard deviation of sample units in the section (usually, taking value of s= 10 [14]).
the results of Al Rahma highway section was illustrated below, For other highways (Al Hizam Al Akhdar, Al Muearid, Al Shamalii garage) using the same area of sample of Al Rahma highway (270) m$^2$. Table (1) show the results of them.
Sample length = \frac{270}{12} = 22.5

N = \frac{1000}{22.5} = 44.44

n = 44.44 \times \frac{10^2}{(5^2/4)} \times (44.44 - 1) + 10^2 = 11.96 \approx 12

i = \frac{N}{n} = \frac{44.44}{12} = 3.7 \approx 4

Then, use first number of sample 1.

So, numbers of samples (s, s+i, s+2i, s+3i, 1+4i, s+5i, s+6i, s+7i, s+8i, s+9i, s+10i, s+11i).

Then the sample sequence will be: 1, 5, 9, 13, 17, 21, 25, 29, 33, 37, 41, 44 for both direction of traffic movement (going from Najaf- Karbala highway and return to it).

### Table 1. Dimension details of four highway sections in Both Direction.

| Highway sections taking in the study | Dimension details |
|--------------------------------------|------------------|
|                                      | Length (m)       | Width (m)    | Sample unit area (m²) | Sample Length (m) | N (total number of sample units) | n (minimum number of sample) | i   |
| Al-Rahma                            | 1000             | 12           | 270                   | 22.5              | 44.44                        | 12                      | 4   |
| Al-Hizam                             | 1440             | 14           | 270                   | 19                | 75                           | 13                      | 6   |
| Al-Akhdar                            | 1400             | 11.25        | 270                   | 24                | 58.33                        | 13                      | 4   |
| Al-Muearid                           | 1930             | 11.25        | 270                   | 24                | 80.24                        | 13                      | 6   |
| Al Shamalii Garage                   |                  |              |                      |                   |                              |                         |     |

### 5. Calculation of the PCI Using PAVER Software:

The PCI value was calculated for the four sections of highways as shown below. Firstly, converting units to the metric units. From PAVER software version 5.2 tool bars menu select “Preference” and then select ”Metric Units” used to convert all dimensions. After that, define the pavement inventory (network, branches, or sections), creation of sample units by using the following steps as shown in figure 6 below as an application for Al-Rahma highway section:

1. Select the button “work” from paver button bar.
2. Press on the "new" to create new project carrying the data of the day.
3. Click on the "PCI" button then select "Edit inspection" to add the new data of inspection and total number of samples.
4. Then click on the "Edit Sample Units" to add the total number of samples and sample size.
5. Entering information on distress (Type, Severity, and Quantity).
6. Click on the "calculation condition".
5.1. Result of Application PAVER 5.2 Software:
After entering the data into the PAVER program, by following the previous steps. The PCI values for Al-Rahma, Al Hizam Al Akhdar, Al Muearid, and Al Shamalii garage highway sections were 80, 48, 58, & 84 respectively in diverging from Najaf- Karbala highway direction. While in the direction of return to Najaf- Karbala highway direction, Al-Rahma, Al Hizam Al Akhdar, Al Muearid, and Al Shamalii garage highway sections gave PCI values equal to 85, 47, 60, and 80 respectively.

5.2. Section Extrapolated Distresses:
PAVER can calculate the section extrapolated distresses directly when click on “section Extrapolated Distresses”. Extrapolated distress deducts are classified as resulting from load, climate, or other. Table (3) showed the section extrapolated distresses that display each type of distress in the sample tab distresses in going from and return to Najaf- Karbala highway direction, respectively. Figure (7) illustrated the main factor caused the pavement deformation.
Figure 7. Main Factor Caused the Pavement Deformation for Highway Sections as Average Values.

Table 2. Results of PCI for Highway Sections Studied

| Direction                        | Highway Section  | PCI value | Condition   |
|----------------------------------|-------------------|-----------|-------------|
| Diverging from Najaf-Kerbala Highway Direction | Al-Rahma          | 80        | Satisfactory|
|                                  | Al-Hizam Al Akhdar| 48        | Poor        |
|                                  | Al-Muearid        | 58        | Fair        |
|                                  | Al Shamalii Garage| 84        | Satisfactory|
| Return to Najaf-Kerbala Highway Direction | Al-Rahma          | 85        | Satisfactory|
|                                  | Al-Hizam Al Akhdar| 47        | Poor        |
|                                  | Al-Muearid        | 60        | Fair        |
|                                  | Al Shamalii Garage| 80        | Satisfactory|
| Average Values                   | Al-Rahma          | 82.5      | Satisfactory|
|                                  | Al-Hizam Al Akhdar| 47.5      | Poor        |
|                                  | Al-Muearid        | 59        | Fair        |
|                                  | Al Shamalii Garage| 82        | Satisfactory|
### Table 3. Percent of Extrapolated Distress for Highway Sections

| Direction                           | Highway Section       | Load % | Climate % | Other Causes % |
|-------------------------------------|-----------------------|--------|-----------|----------------|
| Going from Najaf-Karbala Highway     | Al-Rahma              | 59     | 16        | 25             |
| Direction                           | Al-Hizam Al Akhdar    | 58     | 8         | 34             |
|                                     | Al-Muearid            | 18     | 34        | 48             |
|                                     | Al Shamalii Garage    | 48     | 4         | 48             |
| Return to Najaf-Karbala Highway     | Al-Rahma              | 47     | 24        | 29             |
| Direction                           | Al-Hizam Al Akhdar    | 54     | 10        | 36             |
|                                     | Al-Muearid            | 17     | 38        | 45             |
|                                     | Al Shamalii Garage    | 51     | 5         | 44             |
| Average Values                      | Al-Rahma              | 53     | 20        | 27             |
|                                     | Al-Hizam Al Akhdar    | 56     | 9         | 35             |
|                                     | Al-Muearid            | 17.5   | 36        | 46.5           |
|                                     | Al Shamalii Garage    | 49.5   | 4.5       | 46             |

* Other causes mean all causes other than load and climate factors such as construction materials and procedure, seepage, presence of water in pavement layers and weak subgrade support etc.

### 6. Conclusions

Micro PAVER version 5.2 used in this study, has a good potential and more accurate assessment of the pavement condition index (PCI) and easy to use and understand compared to traditional methods. The following point are the main conclusions obtained from field data analysis:

1. Results of the PAVER software application for the Al Rahma and Al- Shamalii garage highway section are satisfactory in value upper than (80) in both directions going from and return to Najaf-Karbala highway. So based on the value of the PCI it can be concluded that the suitable repair for satisfactory highway sections are preventative maintenance.

2. For Al-Hizam Al Akhdar highway section is poor with PCI under 50. So, best treatment for it is rehabilitation.

3. For Al- Muearid highway section, PCI value less than 60, that is mean this section is fair. Best repair for it is rehabilitation.

4. From the results showed that the traffic load is a dominate reason of defect and climate condition take the secondly reason and the other reason have slightly effect.

5. High quality control of the construction of the road project and the application of early maintenance in the event of distress is recommended to extend road life and reduce maintenance costs.
7. References

1. Afrawee, A. R. M., Aodah, H. H., & Mohammed, H. A. (2020). Development of the Iraqi highways management system-Case study: Basrah–Nasiriyah’s highway. In AIP Conference Proceedings (Vol. 2292, No. 1, p. 030014). AIP Publishing LLC.

2. Al-Neami, M., Al-Rubae, R., & Kareem, Z. (2018). Assessment of Al-Amarah Street within the Al-Kut city using pavement condition index (PCI) and GIS technique. In MATEC Web of Conferences (Vol. 162, p. 01033). EDP Sciences.

3. Asim, B. (2014). Developing Sustainability Performance Measures for Highway Facilities in Iraq. M.Sc. Thesis, Highway & Transportation Department. University of Mustansiriyah.

4. ASTM D6433-11: Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys, West Conshohocken, PA: ASTM International, 2011.

5. Ewadh, H. A., Almuhanna, R. R., & Alasadi, S. J. (2017). Development of Pavement Condition Index Model Using PAVER 6.5. 7 for Flexible Pavement Urban Roads in Karbala City. Journal of University of Babylon, 25(5), 1572-1579.

6. Hallaq, M. A. F. A. (2004). Development of a pavement maintenance management system for Gaza city. Development of a pavement maintenance management system for Gaza city.

7. Hussain F. K. and Al-Jameel H. A, 2018, Investigating Distress Types and PCI for selected road segments in Al-Muthana City, International Journal of Scientific & Engineering Research Volume 9, Issue 12, December ,p. p 988-1004

8. Kandooh N. H. and Al-Jameel H. A, 2019, Evaluating Pavement Condition for Selected Segments of Road Network in Al-Muthanna City, Global Journal of Engineering Science and Research Management, 6(10): October, p. p 1-16

9. Ferman, A. (2016). Multi Objective Optimization Model Using Constraint Based Genetic Algorithms for Iraq Pavement Management. M.Sc. Thesis, Highway and Transportation Engineering, University of Mustansiriyah.

10. M. N. Mahdi and Khawla H.H. Shubber, 2020 Using PAVER Software to Evaluate Pavement Condition Index of Highway Segment in the North Sector of Najaf City (Case Study), IOP Conf. Ser.: Mater. Sci. Eng. 978 012012

11. Knost, B. R. (2016). Evaluating the Accuracy of Pavement Deterioration Forecasts: Application to United States Air Force Airfields (Doctoral dissertation, The Ohio State University).
12. Obaidat, M. T., & Bara’W, A. M. (2012). Integration of Geographic Information Systems and Paver System to Award Efficient Pavement Maintenance Management System (PMMS)–Case Study–Irbid City–Jordan. *Journal of Advanced Science and Engineering Research, 2*(4), 279-296.

13. Obead F.Y., (2012). Development of Pavement Maintenance Alternatives Based on Multi-Criteria System, *M.Sc. Thesis*, Highway & Transportation Department. University of Mustansiriyah.

14. Shahin, M.Y., (2005). Pavement Management for Airports. Roads, and Parking lots. Second edition. Springer Science Business Media, Inc., New York. NY. U.S.A. Smith, R.E.

15. U.S. Army Corps of Engineering-USACE, (2011): PAVER 6.5 User Manual, USA.

16. Zafar, M. S., Shah, S. N. R., Memon, M. J., Rind, T. A., & Soomro, M. A. (2019). Condition Survey for Evaluation of Pavement Condition Index of a Highway. *Civil Engineering Journal, 5*(6), 1367-1383.