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Developing a pavement maintenance management system of multi-lane highway in Iraq

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Abstract. Roads and highways are a major part of the transportation infrastructure in Iraq and play a substantial role in the local economy and community development. This research aims to develop a pavement maintenance management system (PMMS) for the highway which provides a systematic process of maintaining and upgrading the pavement and tools to facilitate a more flexible approach that can enable us to perform better tasks, more economically, effectively and of higher quality. The research study was conducted on a section of the main multi-lane highway in Baghdad, from Al- Dora intersection to Al-Mahmudiya district. The study area was divided into (20) sections. Each section divided into (40) sample units with size (250) m². This highway is considered as a major highway with high traffic volume in Iraq. The updating Micro PAVER v.7.0.8 software was used for assessment and prediction of the condition of highway pavement and maintenance cost for existing conditions (Time of the study survey has occurred in 2018), the maintenance plan has been for short-term conditions (2018-2023) and medium-term conditions (2018-2027). The study shows that the PCI of the existing conditions was rating as (poor) with 90,434.00$ maintenance cost. The PCI of short-term condition was the rating (satisfactory) with 13, 497, 448, 00$ maintenance cost. The PCI of medium-term condition was the rating (good) with 18, 756, 142, 00$ maintenance cost. All highways in Iraq needs to be reconsidered for future maintenance plans to improve the quality of service of these facilities.

1. Introduction

Roads and highways are a major part of the transportation infrastructure in Iraq and play a substantial role in the local economy and community development. Iraq's transport infrastructure has suffered from more than three decades of neglect and underinvestment from 1980 until now. The regional conflicts, the utilization of public resources to support military initiatives, an extended period of economic sanctions, and postponement maintenance contributed to a pernicious and general decline in the quality of transport facilities and services. With the growing number of vehicles, the quality of service decreased, so that it became necessary to study the causes of the problem and find the appropriate solutions, either for the current or future conditions. Pavement maintenance is one of the major issues of public agencies. Insufficient investment or inefficient maintenance strategies led to high economic expenses in the long term. Furthermore, Pavement Maintenance Management System (PMMS) considered a scientific tool for managing the pavements to make the best possible use of resources available or to maximize the benefit for society [1, 2].

Other studies that discussed field data acquisition technology was developed [3].This study describes the results of the research project investigating the use of advanced field data acquisition technologies. Further, researchers will be capable to perform real-time operations, extract highly accurate data, present spatially inventory data, introduce numerous analytical techniques and develop a highly technological system. Maintenance and operation engineers were also anticipated to use the findings and guidelines of this research work to automate most of their routine decision-making activities Al-Mestarehi [4]. The PMMS was developed with a visual inspection technique for evaluating the Asphalt Concrete pavement surface condition. The common types of Asphalt Concrete distress include (bleeding of Asphalt, patching, block cracking, edge cracking, longitudinal and transverse cracking, rutting, potholes, longitudinal and transverse deformation) with their various severity and intensity conditions have been included in the system as the database, the surface of the pavement was divided into sections, and the pavement condition is visually evaluated by the ratters using specially designed forms, each type of defect was measured, classified, and rated according to type, severity, and extent. Data was fed to the system using the computer. The developed system was verified in evaluating the pavement surface condition at the AL-Jaderiah campus roadway network Sarsam and Abduluhameed [5]. Obead [6] 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 [7] stated that the maintenance of transportation assets has become a worst challenge for most of the transportation agencies over the world. A system was presented to facilitate the decision-making process for highway pavements. It is based mainly on the direct integration between Micro PAVER as a pavement software and Geographic Information System (GIS) software in order to fully exploit the capabilities of each individual package. In this research, the updating Micro PAVER v. 7.0.8 software was used, which was developed by the Colorado State University PAVER provides many important capabilities [8, 9]. It is a decision-making tool for the development of cost-effective maintenance and rehabilitation for Highways [10].

2. Case Study

The studied section of the multi-lane highway is about 20 km long between the freeway system and the expressway, as shown in Figure 1. The selected section of highways is very heavy traffic volume with high Annual Average Daily Traffic (AADT) [11], especially during a special event with a high percentage of trucks and buses that effect on the surface layer of the flexible pavement causing high distress and cracking. It needs to be evaluated and improved in order to provide a high quality of service for the traffic flow.

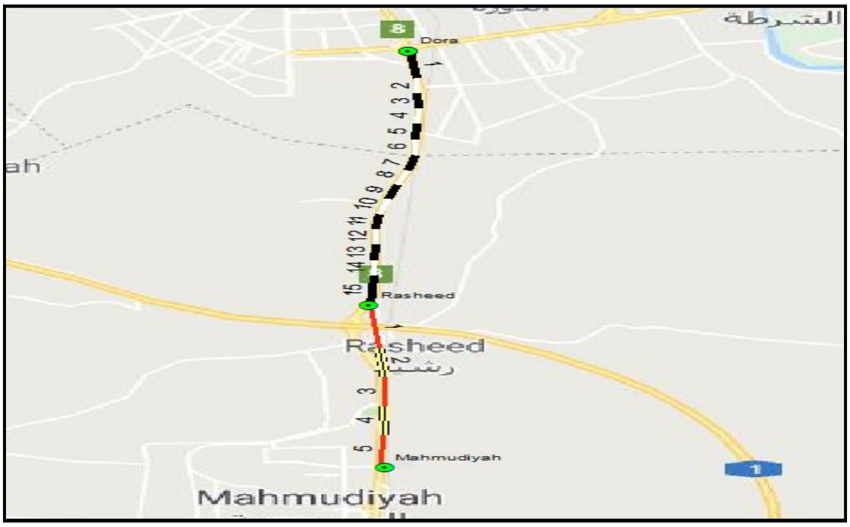

Figure 1. Map of Study Area, from Al- Dora Intersection to AL-Mahmudiyah district

3. Methodology of PMMS

The Research methodology of PMMS to a specific pavement network is completed with a systematic procedure that involves a variety of tasks on a periodic basis. The research methodology consists of the following main steps: Obtain maps, Define network, data inventory, determining Maintenance and Rehabilitation (M&R) needs and priorities and selecting the most cost-effective M&R alternative, predicting models for pavement performance deterioration, and generating pavement management reports as shown in Figure 2. This procedure is used worldwide with very little variation [12].

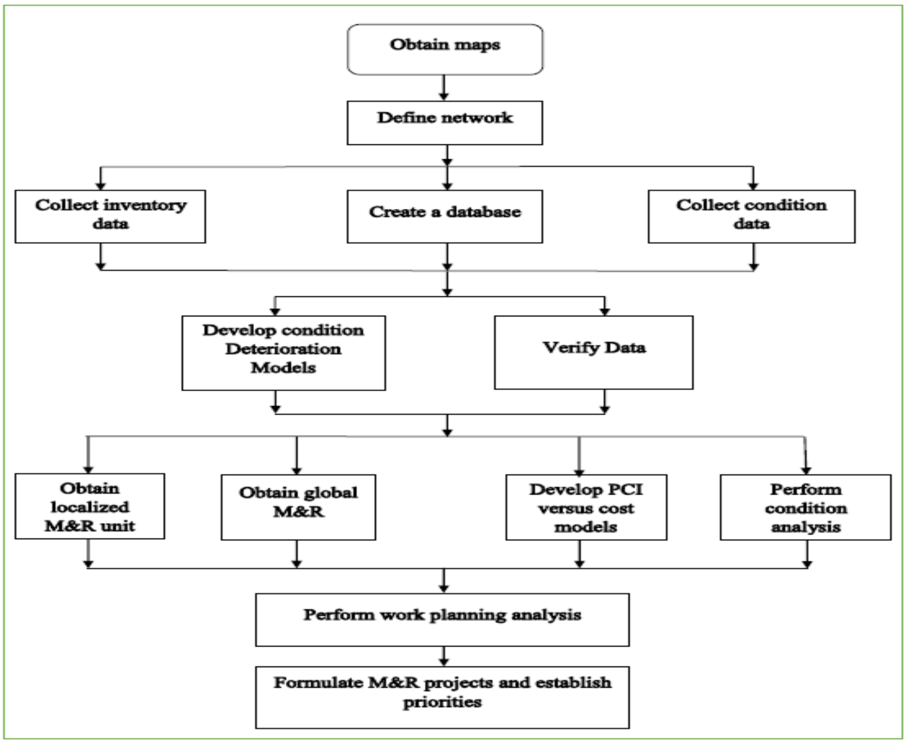

Figure 2. PMS Implementation steps [12]

3.1. Data Collection and Analysis

3.1.1. Field Data Collection

The following steps describe the collected data in the study area.

3.1.1.1. Pavement condition

Pavement condition is usually evaluated by present condition index PCI which is a numerical index between 0 and 100 which is considered as a measure rating system where 0 is the worst possible condition and 100 representing the best possible condition as can be seen in Figure 3 [13].

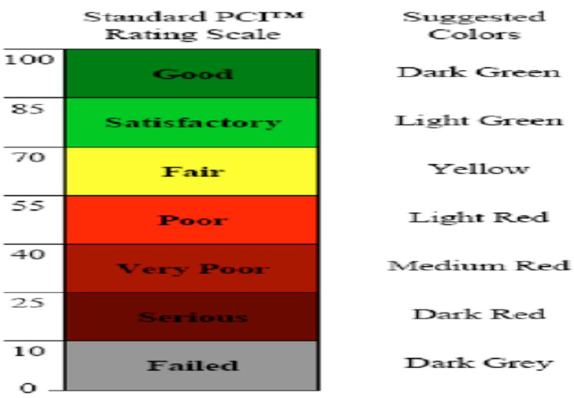

Figure 3. Pavement Condition Index (PCI), Rating Scale, and Suggested Colours [13]

3.1.2 Visual Survey

The study area was divided into two branches, Dora -Rasheed (ER8A) branch as (inbound) and Rasheed – Mahmudiyah (ER8B) branch as (outbound), it was divided to 15, 5 sections respectively as shown in Figure 4. These sections were divided into inspection units called sample units, after collecting distress data, which include; distress type, severity, and quantity, the value of PCI was estimated for the sample units and PCI for the pavement sections by using Micro PAVER 7.0.8 software.

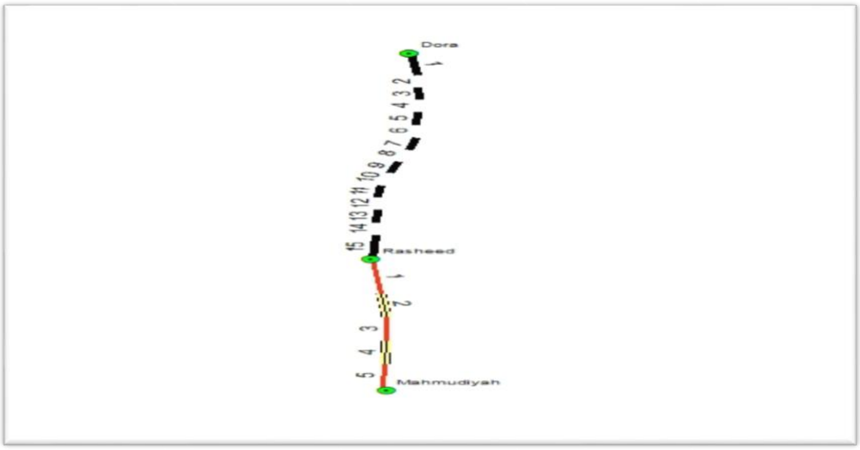

Figure 4. Sections of the study selected for inspection (by using ArcGIS)

3.2 Data Component

3.2.1 Data Inventory

There are two sets of data that was obtained from information provided by Mayoralty of Baghdad (MOB) and from field inspection which conducted by the researcher.

The data includes the following:

- Name of the road.
- Segment ID of the road.
- ADT data.
- Construction year of the road.
- Classification of the road.
- Road length, width, and number of lanes.
- Arc GIS shape file for the road segment that was used as case study area.
- Pavement Condition Survey

3.2.1.1 Divided pavement sections into sample units

The first step in performing an inspection survey was dividing the pavement section into sample units for an asphalt road. The sample unit has a standard size range according to the ASTM standards for the airfield and roads D6433-09 [14] for asphalt road, 2500 square ft ± 1000ft (225±90 m^2).

Each section has area 10000 m^2 (1000 m long, 10 m wide), and subdivided into many sample units each unit has area 250 m^2 (25 m long and 10 m wide). So the section was divided into 40 units.

3.2.2 Determine the Number of Sample Units to be inspected

Due to the limitation of resources and required budget, a sampling plan was developed so that reasonable estimation of the PCI (Evaluation of a given road) could be determined by inspecting only a portion of the sample units in the pavement section.

The first step in performing the inspection by sampling is to develop the minimum number of sample units (n) that must be surveyed to obtain a statistically adequate estimate (95% confidence) of the PCI of the section. The statistical sample size can be calculated, according to ASTM standards for the airfield and roads D6433-09, using the following formula. The result is rounded to the next high whole number

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

Where:
e= acceptable error in estimating the section PCI; commonly,
e=±5 PCI points
s= standard deviation of the PCI from one sample unit to another within the
Section

When performing the initial inspection, the standard deviation is assumed to be ±10 for AC pavements. N= total number of sample units in each section, which are 40 units.

Therefore, by applying the above formula the minimum number of sample units to be inspected for each section was found to be 11.63 (n= 12).

The spacing interval of units can be obtained using random sampling; sampling interval (i) of the units to be sampled was calculated based on D6433-09, by the following formula and rounded to the next lowest whole number:

$$i = N/n \quad (2)$$

Where:
i = sampling interval
N= total number of sampling units in the section, which is 40
n= number of sampling units to be inspected, which is 12
i = 40/12
i = 3.3

Based on the above, the spacing interval was found to take 3. The sample units to be surveyed are sections 3,6,9,12,15,18,21,24,27,30,33 and 36 as shown in Figure 5.

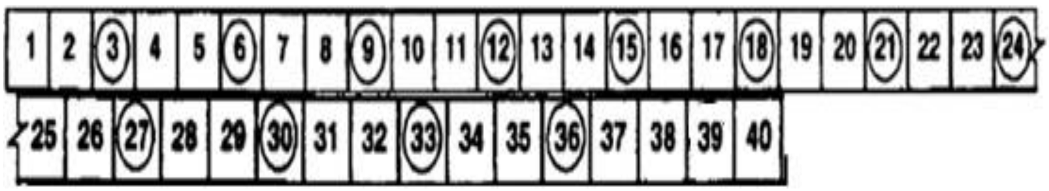

Figure 5. The Selected Sample Units for Inspection

3.3. Analysis Component

3.3.1 Current pavement evaluation

Condition survey was conducted for each sample unit, after that the distress information was entered into Micro PAVER software in order to calculate current PCI. The software uses the previous data to calculate the deduct value for each type of defect. The program calculates the Pavement Condition Index (PCI), Structural Condition Index (SCI) and Standard Deviation output for every section and determine PCI for each inspected sample unit using deduct value and prediction the highway pavement condition, then was categorized based on PCI values using the criteria shown in Table 1. At the time of inspection, the highway pavements were found to be in overall “poor” condition, with an overall average PCI of 49.86 for branch ER8A and 50.80 for branch ER8B. The condition distribution of pavement sections at the time of the inspection is shown in Tables 2 and 3 which illustrates the pavement condition by pavement sections.

Table 1. Pavement Condition Assessment Criteria

Condition assessment	PCI value
Failed	0-10
Serious	10-25
Very poor	25-40
Poor	40-55
Fair	55-70
Satisfactory	70-85
Good	85-100

Table 2. Current PCI Output for Branch ER8A, for All Sections

Branch ID	Section ID	PCI Value	Condition	SCI Value	Std.dev
ER8A	ER8A1	59	Fair	68	20.13
ER8A	ER8A2	58	Fair	69	18.46
ER8A	ER8A3	58	Fair	62	18.18
ER8A	ER8A4	47	Poor	50	13.60
ER8A	ER8A5	47	Poor	53	13.24
ER8A	ER8A6	54	Poor	58	11.47
ER8A	ER8A7	44	Poor	47	12.68
ER8A	ER8A8	36	V. Poor	42	14.02
ER8A	ER8A9	38	V.Poor	42	19.76
ER8A	ER8A10	43	Poor	48	13.44
ER8A	ER8A11	45	Poor	54	14.43
ER8A	ER8A12	49	Poor	56	14.73
ER8A	ER8A13	51	Poor	55	15.43
ER8A	ER8A14	52	Poor	58	21.34
ER8A	ER8A15	67	Fair	70	13.72

Table 3: Current PCI Output for Branch ER8B, for All Sections

Branch ID	Section ID	PCI Value	condition	SCI Value	Std.dev
ER8B	ER8B1	59	Fair	64	14.00
ER8B	ER8B2	62	Fair	65	14.06
ER8B	ER8B3	49	Poor	54	19.26
ER8B	ER8B4	34	V.Poor	39	11.45
ER8B	ER8B5	50	Poor	56	17.80

3.3.2. Prediction of Pavement Condition for Five Years

After calculating the current PCI for each branch section, the future pavement condition was evaluated and performed at section level then aggregate to produce branch highway results. Micro PAVER program output result predicts PCI pavement condition for branch ER8A"Dora-Rasheed" and ER8B"Rasheed-Mahmodia" for the next five years as illustrated in Figure 5 and 6. The Figures show that the PCI for branch ER8A decrease from 49.75 in 2018 to 42.01 in 2022 and PCI for branch ER8B decrease from 50.71 in 2018 to 43.93 in 2022.

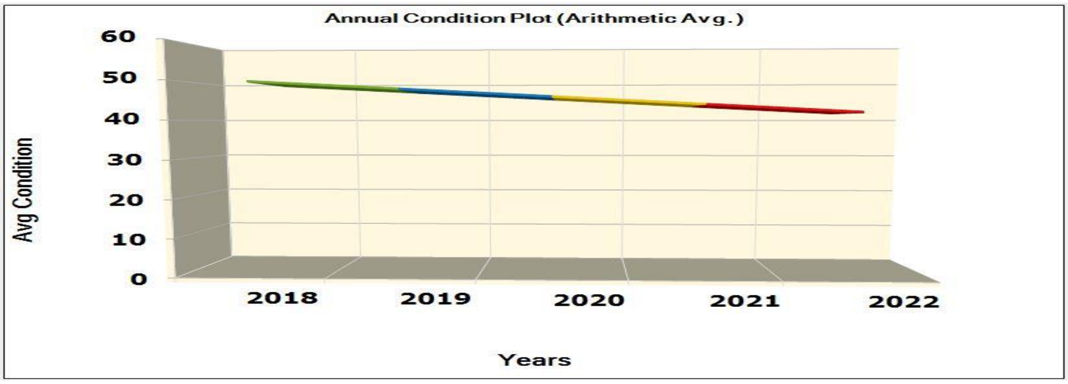

Figure 5. Future pavement condition for five years for Branch ER8A

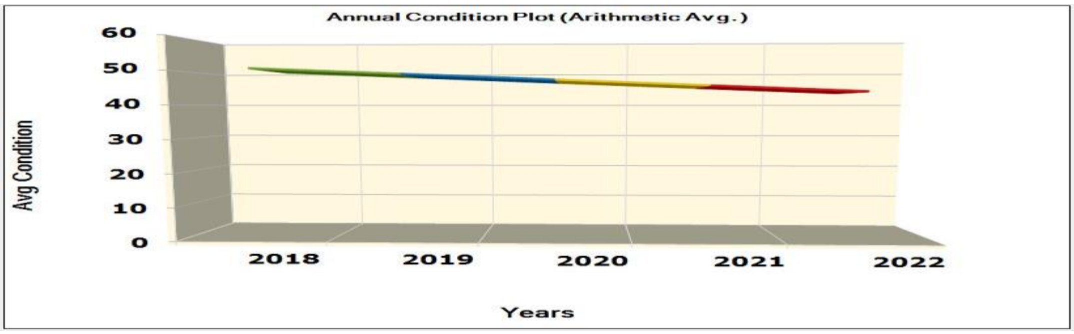

Figure 6. Future pavement condition for five years for Branch ER8B

For each year of prediction, the conditional distribution for the sections in the branch was calculated. Figure 7 shows the condition distribution among sections for the branches for the next five years.

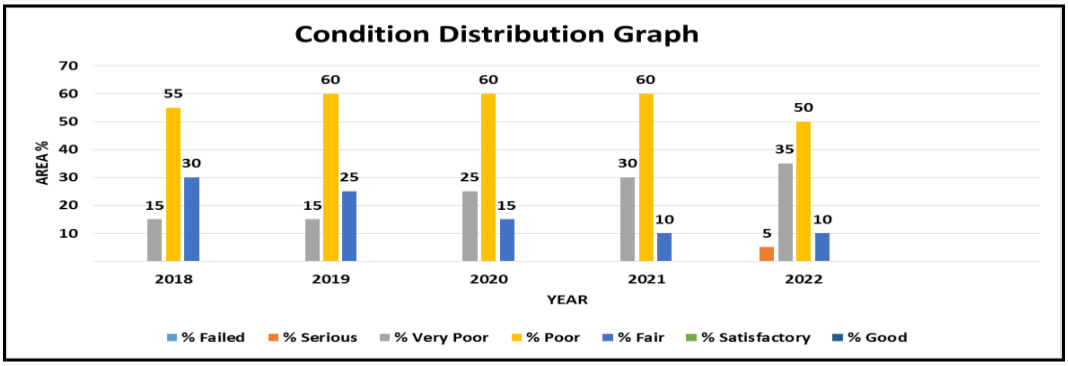

Figure 7. Condition Distribution Graph for the next five years

3.3.3. Prediction of Pavement Condition for ten years

Micro PAVER program output result predicts PCI pavement condition for branches ER8A“Dora-Rasheed” and ER8B“Rasheed-Mahmodia” for the next ten years as illustrated in Figures 8 and 9. The Figures show that the PCI for branch ER8A decrease from 49.75 in 2018 to 32.32 in 2027 and PCI for branch ER8B decrease from 50.71 in 2018 to 35.45 in 2027.

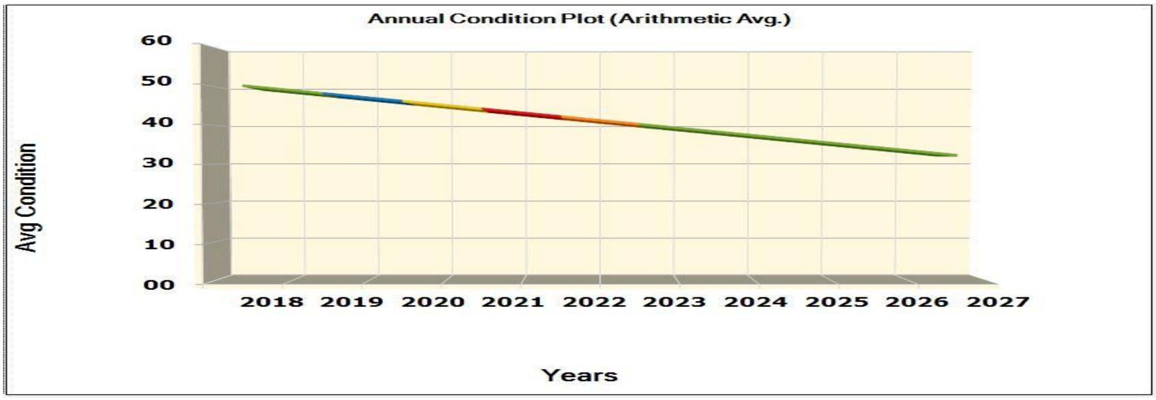

Figure 8. Future pavement condition for ten years for Branch ER8A

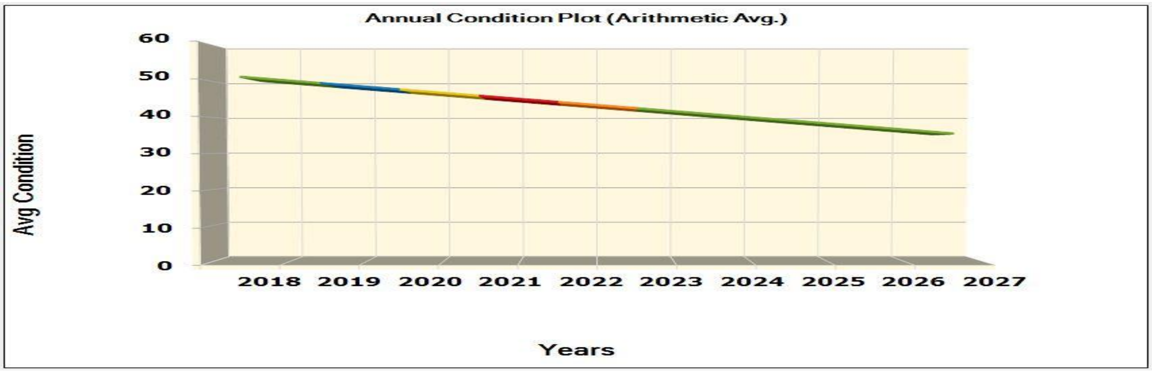

Figure 9. Future pavement condition for ten years for Branch ER8B

Figure 10 shows the condition distribution among sections for the branches for the next ten years.

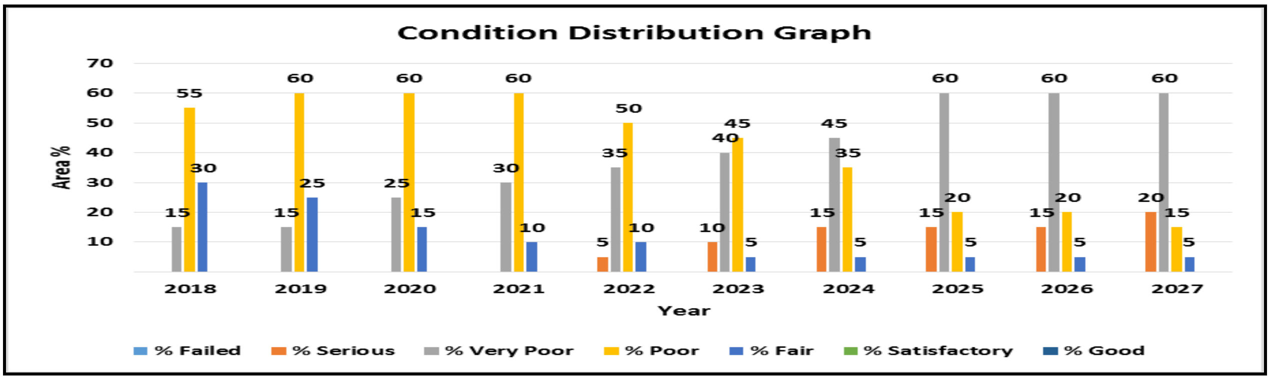

Figure 10. Condition Distribution Graph for the next ten years

3.3.4 Maintenance Plan Component

The maintenance plan short and medium-term work plan will be prepared once the inspection and construction history data have been entered into the Micro PAVER software, it can be used to develop an annual and long-term work plan.

Micro PAVER allows the user to possible maintenance activities for each type of local and major maintenance along with the cost of each activity, and then integrate all of the gathered information and compute annual and M&R plan for a specific length of time-based on the available budget. Annual, five years and ten years maintenance plan were done with Micro PAVER software.

The following procedure and assumption are used in developing M&R plan for the study area:

- The optimization was done using the critical PCI method, which is based on the principle that it is more economical, on a life-cycle cost basis, to maintain pavements above rather than below the critical PCI. The critical PCI is the PCI value below which the rate of deterioration as well as the unit cost of performing localized preventive M&R.

- Increases significantly.

3.3.4.1. Existing year (2018) M&R plan

The existing year plan shows the condition before and after the plan also show the estimation budget need to plan the branches, it can also be conducted to each section in the branches. As shown in Table 4.

Table 4. Existing Year Estimation Budget

Plan year	Sum of StopGAP Funded/$	Sum of preventive funded/$	Sum of Major Under Critical Funded/$	Sum of Major Above Critical Funded/$	Total/$
4/6/2018	56,730.00	33,704.00			9,434.00

Table 5 shows the existing year M&R plan for section ER8A4.

Table 5. Existing Year M&R Plan for Section ER8A4

Plan Year	Avg PCI condition before	Avg PCI condition after	Maintenance	Sum of stop gap Funded/$	Sum of Major under Critical Funded/$	Total/$
4/6/2018	46.90	46.90	Stop gap	1,410.00		1,410.00

3.3.4.2. Five years M&R Plan (Short-term)

The five-year plan shows the condition before and after the plan also show the estimation budget need to plan the branches, it can also be conducted to each section in the branches. Figure 11 illustrates the summary of five years M&R plan for condition before and after maintenance for the branches.

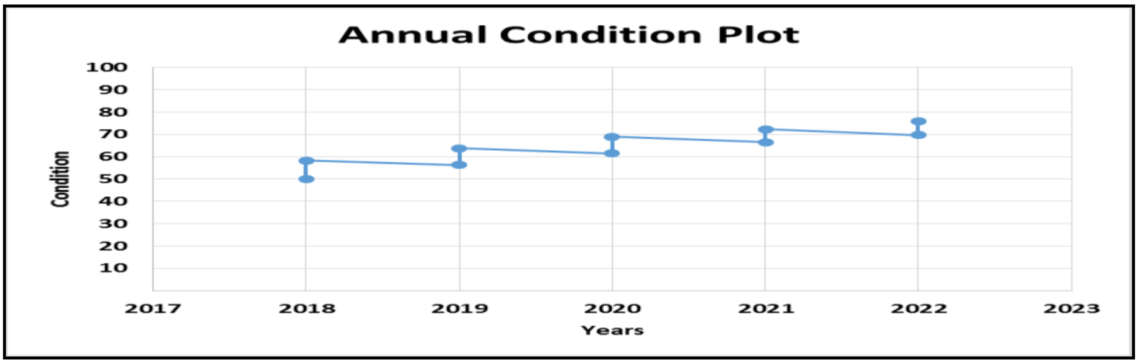

Figure 11. Five Years PCI Plot before and after repair (2018-2022)

Table 6 shows the five years estimation budget for branches, each policy applied cost is defined as shown. For example in 2018 the sum of stopgap was 47,684.00$ which calculated by summation the stopgap cost for sections in the branches that had stopgap work, the sum of preventive was 33,498.00$ which was calculated by summation the preventive work funded for sections in the branches that had preventive work, the sum of major maintenance under critical was 2,792,264.00$ which was calculated by summation the major maintenance for sections in the branches that had major maintenance work when its PCI is less than the critical.

Table 6. Five Years Estimation Budget for two directions

Plan year	Sum of Stop GAP Funded/$	Sum of preventive funded/$	Sum of Major Under Critical Funded/$	Total/$
4/6/2018	47,684.00	33,498.00	2,792,264.00	2,873,446.00
4/6/2019	47,232.00	36,038.00	2,839,412.00	2,922,682.00
4/6/2020	49,406.00	16,416.00	2,777,522.00	2,843,344.00
4/6/2021	57,180.00	17,498.00	2,259,590.00	2,334,328.00
4/6/2022	68,574.00	20,492.00	2,434,582.00	2,523,648.00

Figure 12 shows a condition plot for five years M&R plan for the condition after applying the plan in year 2021 the condition become 100 after applying major maintenance for one direction.

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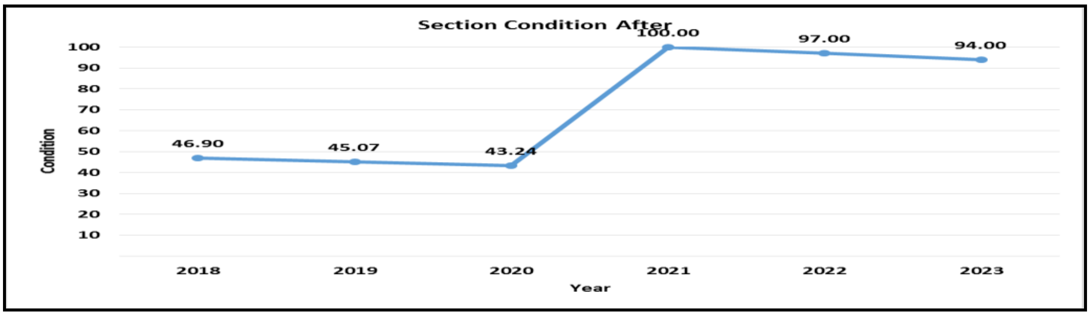

Figure 12. Typical Five years M&R plan condition plot for section ER8A4

3.3.4.3 Ten years M&R Plan (Medium-term)

The ten-year plan shows the condition before and after the plan also show the estimation budget need to plan the branches, it can also be conducted to each section in the branches. Figure 13 illustrates the summary of ten years M&R plan for condition before and after maintenance for the branches.

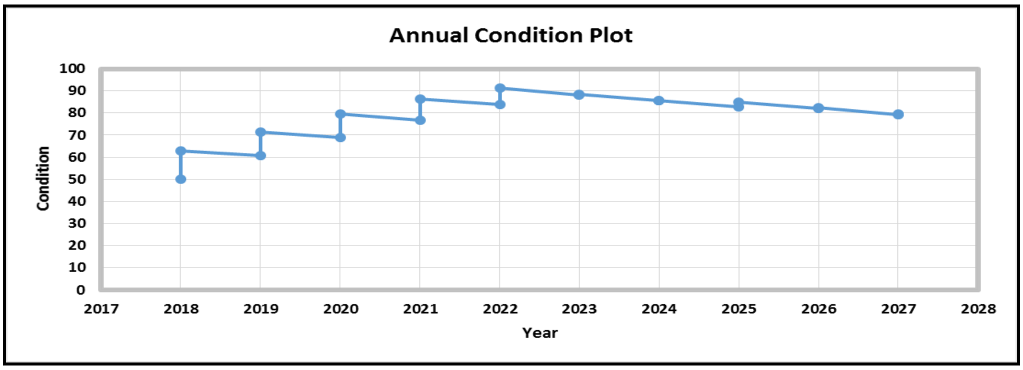

Figure 13. Ten Years PCI Plot before and after repair (2018-2027)

Table 7 shows the ten years estimation budget for branches, each policy applied cost is defined as shown. For example in 2018 the sum of stopgap is 43,328.00$ which calculated by summation the stopgap cost for sections in the branches that had stopgap work, the sum of preventive is 33,478.00$ which calculated by summation the preventive work funded for sections in the branches that had preventive work, the sum of major maintenance under critical is 4,059,282.00$ which calculated by summation the major maintenance for sections in the branches that had major maintenance work when its PCI is less than the critical.

Table 7. Ten Years Estimation Budget for Two Direction

Plan year	Sum of Stop GAP Funded/$	Sum of preventive funded/$	Sum of Major Under Critical Funded/$	Total/$
1/6/2018	43,328.00	33,478.00	4,059,282.00	4,136,088.00
1/6/2019	39,112.00	36,018.00	3,484,840.00	3,559,970.00
1/6/2020	34,880.00	16,404.00	3,647,374.00	3,698,658,00
1/6/2021	29,694.00	17,588.00	3,661,236.00	3,708,518.00
1/6/2022	0.00	21,342.00	2,798,616.00	2,819,985.00
1/6/2023	0.00	27,764.00	0.00	27,764.00
1/6/2024	0.00	36,556.00	0.00	36,556.00
1/6/2025	0.00	25,712.00	618,06.00	643,774.00
1/6/2026	0.00	47,666.00	0	47,666.00
1/6/2027	0.00	77,190.00	0	77,190.00

Each number in Table 7 plan come from the total works cost for the sections in the branches, ten years M&R plan was conducted to each section in the branches in two directions.
Figure 14 shows a condition plot for ten years M&R plan for the condition after applying the plan in the year 2020 the condition becomes 100 after applying major maintenance for one direction.

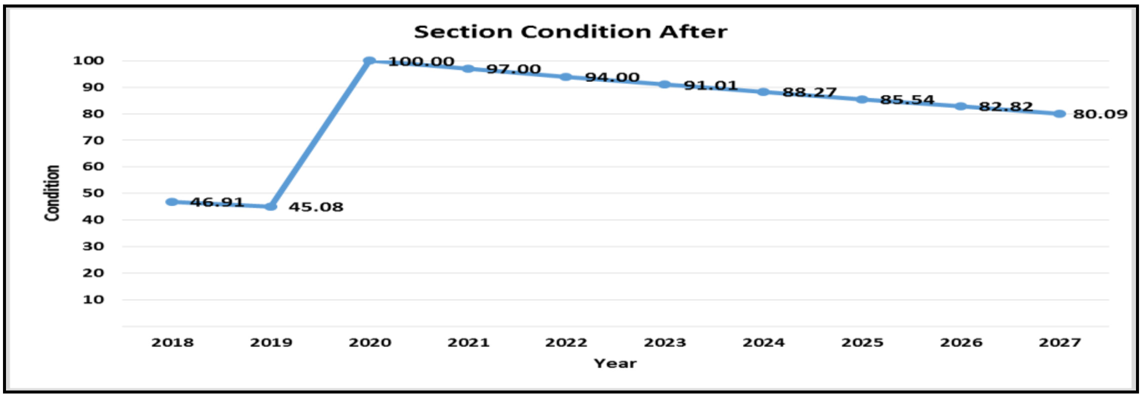

Figure 14. Typical Ten-year M&R plan condition plot for section ER8A4

3.4 Implementation Component

The final step was to generate reports to communicate the result of the analysis the report for the whole branch includes the following:

- Inventory report that used to view pavement inventories.
- Work report that used to view pavement work history.
- Condition assessment report (PCI report) that used to display the PCI of the sections at the time of the last inspection.
- Condition Analysis report that used to show the prediction of the future pavement performance.
- M&R report that used to generate M&R plans for annual and five years plan.
- GIS maps that used to graphically display PCI information on a shape file.

4. Conclusions

The main conclusions that can be drawn from this research are summarized as follows:

1. Micro PAVER 7.0.8 software has a good ability and more accurate to estimate pavement condition index (PCI) to decrease expected errors related to conventional method.

2. The traditional PMMS that is currently in use in MPWH cannot help in decision making for enhancing the maintenance activates to match the road user's expectation, therefore, a PMMS is required to make the system more flexible to adjust work plan and schedule to reflect changing condition.
3. The condition survey shows that the deterioration observed in the study area pavement was caused primarily by a mixture of climate and load-related distresses.
4. The condition survey shows that approximately 55% of sections surveyed were in "Poor" condition, 30 % of the sections were rated as "Fair" condition, 15% of the sections were in "very poor". Ideally, these sections should receive maintenance as soon as possible to avoid costly maintenance actions in the future. Overall, the branch had an average weighted PCI of 50 which considered as "poor" rating.
5. By using the Micro PAVER PMS, a future prediction of PCI for five years duration was performed and that shows a reduction in PCI value from 49.99 in 2018 to 42.49 in 2022.
6. By using the Micro PAVER pavement management system, five years and Ten years M&R budget analysis was performed on study area pavements.
7. The average PCI after application of M&R analysis for both branches shows that the PCI condition increases from 58.33 in 2018 to 75.85 in 2022 which is about 30%.
8. This research shows that both Micro PAVER and ArcGIS can be good tools for enhancing the management process of Iraq pavement highways since it assists in developing and organizing inventory, assessing the current condition of highway pavement.

References

[1]. Bryar Qadir Ahmed 2013 *Developing of Pavement Management System (PMS) for EMU Campus Pavement in GIS Environment*, Master Thesis, Eastern Mediterranean University, Cyprus.

[2]. Cristina et al., 2014 An Iterative Approach for the Optimization of Pavement Maintenance Management at the Network Level, *the Scientific World Journal*, **Vol. 2014**.

[3]. Jaselskis EJ 2009 Field Data Acquisition Technologies for Iowa Transportation Agencies Iowa DOT Proj HR-366, ISU-ERI-Ames-**94409**, Pagination.

[4]. Al-Mestarehi B W 2009 *Integration of GIS, and PAVER Systems to award Pavement Maintenance Management System (PMMS)* M.Sc Thesis Department of Civil Engineering, Jordan University of Science and Technology: Irbid, Jordan.

[5]. Sarsam S I and Abdulhameed AT 2014 Development of Pavement Maintenance Management System for Baghdad Urban Roadway Network, *Journal of Engineering*, **20(**3).

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

[7]. Faris F G and Mahir M D 2012, Using of Modern GIS in Road Condition Index, *Journal of Advanced Science and Engineering Research* **2**(3), pp. 178-190.

[8]. Norlela I A and Riza A 2009 An Overview of Expert Systems in Pavement Management, European Journal of Scientific Research, **30**(1), pp. 99-111.

[9]. U.S. Army Corps of Engineering-USACE, (2011), Micro Paver 6.5 User Manual, USA.

[10]. ASHTO 2004 Achieving Flexibility in Highway Design. *American Association of State Highway and Transportation Officials* Washington, D.C.

[11]. Basim Jrew, Ahmad H M and M Msallam 2019Evaluation and Improvement of Multi-lane Arterial Highway in Iraq, *Journal of Engineering and Applied Sciences*, **14**(5), pp. 8997-9004.

[12]. Shain M Y 2005 *Pavement Management for Airports, Roads, and Parking Lots*, Chapman and Hall: New York.

[13]. ASTM D6433-7 2007 *Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys*, ASTM International, West Conshohocken, PA.

[14]. ASTM D6433-09 2009 *Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys*, ASTM International, West Conshohocken, PA

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