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# Pavement Maintenance Applications using Geographic Information Systems

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**Abstract**

The aim of this work is to develop a Pavement Maintenance Management System (PMMS) for the roads and parking network. An extensive review was carried out on previous PMMS projects used for roads in Jordan and other countries. This research focuses on the software called PAVER system that is used to create a comprehensive and integrated database and GIS-based map layers for the road pavement and engineering characteristics. The research will contribute to the provision of a systematic method for the control of the Maintenance and Rehabilitation (M&R) process for paved networks. Although many researches in Jordan discuss reasons and procedures for M&R of road networks, there is still a lack of the systematic strategy and prediction procedure.



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*Keywords:* maintenance and rehabilitation; pavement maintenance management system; pavement condition index; roads and parking network

## 1. Introduction

Managing paved networks such as roads, parking lots, pedestrians' sidewalks, walkways and yards is an important issue in Al-Zaytoonah University of Jordan as well in other universities and organizations, which includes large paved areas utilized as parking spaces and students' bus terminals. A PMMS can be a useful tool for evaluation and prioritization of M&R projects, determination of funding requirements and optimum allocations. The development of Pavement Management System (PMS) products has supported systematic and economic management of pavements [1, 2]. The maintenance at early stages of pavement deterioration proved to produce large savings before the start of the costly sharp decline in pavement condition as clearly illustrated in Fig. 1.

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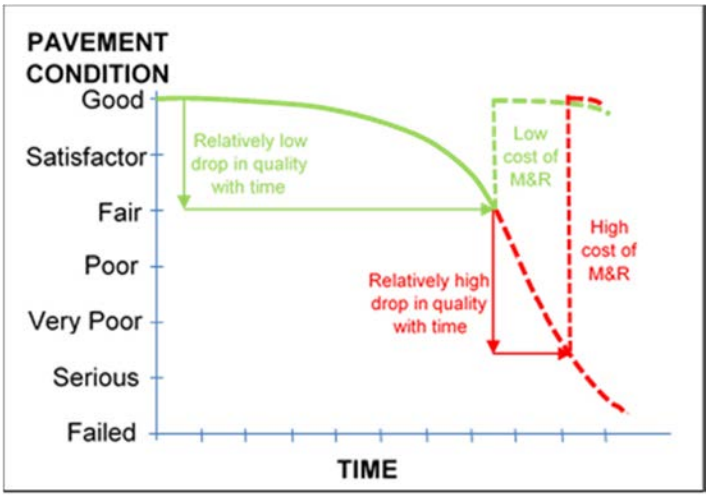



Fig. 1. Illustration of Pavement Condition Variability with Cost of M&R over Time.

## 2. Literature Review

Many researchers have studied the performance of paved networks and the probable factors that caused distresses. It was concluded that trucks with axle loads exceeding the legal limit, poor designed drainage systems and lack of quality control are the most probable causes for deterioration of road network in Jordan [3].

The relationship between roads pavements failures, engineering indices and underlying geology of sub-grade layers were studied [4]. It was noted that roads with high failure rates are supported by poor sub-grades, whereas highways with low failure rates are supported by weathered sub-grades. The researchers also emphasized the provision of drainage systems to reduce rates of road failures.

Some researchers stated that rutting has gradually developed in the wheel path due to increasing number of traffic repetitions under hot weather [5]. They illustrated that rutting phenomenon is the result of both consolidation, which occurs at earlier stages of pavement service life, and shear deformation. Some researches have evaluated the condition of road network in Jordan by using Maintenance Management System (MMS). Other researchers [6] studied pavement condition for selected road sections in Amman city by using Micro PAVER system. They considered three classes of roads including arterial, collector and local roads. The authors claimed that the roads condition in western Amman is relatively better than eastern Amman, and it is better in Amman than other governorates. There were projects in which computer software were used as a part of MMS. Some projects incorporated Micro PAVER system for the evaluation of 153 pavement sections in Irbid city [7]. It was concluded that 70% of the pavement sections require different levels of maintenance treatments.

There were also some attempts to develop a review and analysis of the pavement management system currently adopted by the Ministry of Public Works and Housing (MPWH) in Jordan [8]. Suggestions and opportunities for the improvement of the existing system were proposed. Other researches also noted that Pavement Management System (PMS) approach can be used to set priorities for maintenance and repair while including a provision for the evaluation of pavement performance on a periodic basis to identify sections with a need for maintenance [9].

## 3. Research Objectives

The aim of this research project is to develop a Pavement Maintenance Management System (PMMS) for the roads and parking network in Al-Zaytoonah University of Jordan (ZUJ). Research objectives can be summarized as follows:

- Developing of a comprehensive and integrated database for the road pavement at Al-Zaytoonah University of Jordan (ZUJ)

- Developing a Geographic Information System (GIS) based map layers for the road network inventory and engineering characteristics such as traffic volumes, material properties, pavement thickness, drainage system, etc.
- Evaluating the pavement condition using the Micro PAVER system, which was developed by the U.S. Army Corps of Engineers
- Estimating the M&R quantities and costs for all pavement sections in the road network.

## 4. Research Methodology

The Micro PAVER system was used to create a comprehensive and integrated database in addition to a GIS based map layers for the road pavement and engineering characteristics. Field survey was conducted to evaluate the Pavement Condition Index (PCI) for the selected pavement sections. M&R quantities were estimated. The methodology that is used to fulfill the research objectives can be summarized as follows:

Task 1: Intensive literature review of related resources.
Task 2: Reviewing the construction and maintenance records of the road network at ZUJ.
Task 3: Developing the engineering database for the road network using GIS.
Task 4: Dividing the road network into branches and pavement sections using the Micro PAVER system.
Task 5: Evaluating the selected pavement sections in order to determine the Pavement Condition Index (PCI).
Task 6: Estimating M&R quantities and costs for each pavement section.

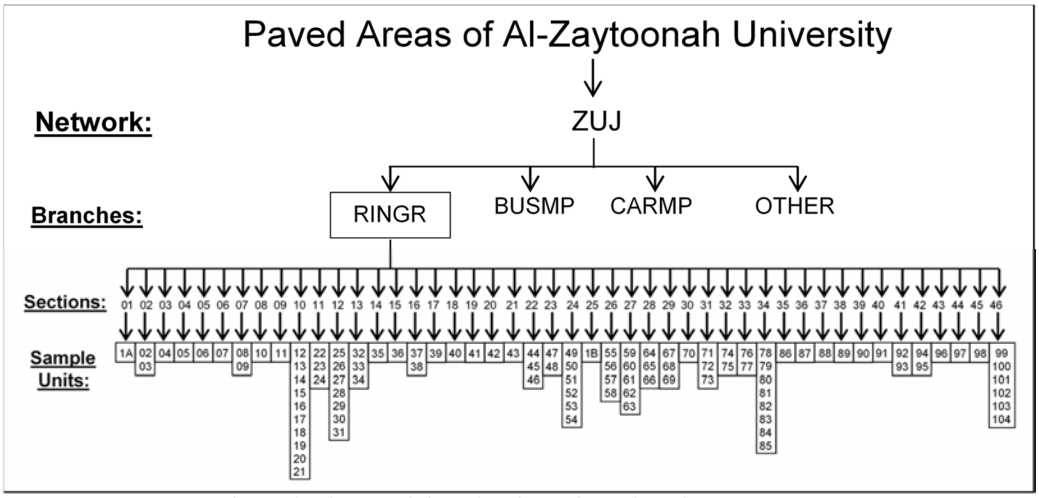
## 5. Pavement MMS Process

### *5.1. Inventory definition*

The first step in establishing a PMMS is the definition of an inventory that organizes paved areas. The paved areas can be grouped into networks, branches and sections. The classification used at Al-Zaytoonah University is presented in Fig. 2.

The paved areas were considered as one network since they are all generally located in the same geographical position while funded by the same organization and constructed in compliance with relatively similar standards and specifications. The network of the university then was divided into branches to represent the identifiable parts of the paved areas. Therefore, four branches were chosen to represent the main streets and parking lots in the university. Only the procedure and results for one branch of the university network named Ring Road (RINGR) is presented in this paper.

Each branch was divided into sections. For practical objectives, sections should be classified to identify areas with relatively consistent characteristics. In this study, characteristics of the paved areas, such as dimension of cross-section, surface condition, traffic type and volume, construction history, and condition of shoulders were considered. A short count of vehicular volumes was conducted on a number of key junctions and intersections within the network at the university to estimate traffic volumes. The traffic volumes data and load intensity of traffic vehicles which use the paved network of the university were considered in the determination of pavement sections.




RINGR: Represents the main ring road that circulates the university
BUSMP: Represents the main bus terminal (park) lots
CARMP: Represents major car parking lots

Fig. 2. Grouping and Clasification of Paved Areas in Al-Zaytoonah University.

### *5.2. Pavement condition evaluation*

The aim of this step is to determine the current condition of the different paved areas. Rating procedure that uses Pavement Condition Index (PCI) developed by the U.S. Army Corps of Engineering was adopted to evaluate the pavement distresses condition in each pavement section [1]. This rating procedure uses a scale of 100 points that depends on the type, quantity and severity of the distresses to rate the condition of the road sections, as shown in Fig. 3.

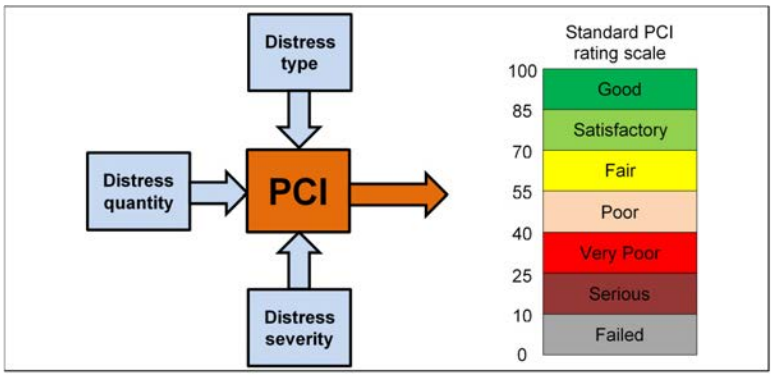



Fig. 3. Rating scale used for Pavement Condition Index (PCI) Method.
Source: [2].

The first step in this method is to divide each pavement section into sample units. Sample units are the pavement areas designated for pavement inspection. In this study, sample unit sizes were defined to be almost equal for each pavement section and to be in the range from 140 $m^2$ to 340 $m^2$. Due to the fact that the size of the paved areas in the university is relatively small, and a high degree of accuracy is preferable for project development, all defined sample units underwent inspection during the study. Data for the evaluation of each sample unit was recorded in an appropriate

PCI survey sheet designed for this study. Fig. 4 shows examples of distress types which were encountered in the studied pavement network.


Fig. 4. Examples of pavement distress types from the site of study.

## 6. Results

PCI calculations were conducted by using the manual-based and software-based methods. The results of the PCI calculations for the pavement sections are summarized in Table 1. There are some slight differences between the results of the two methods. However, on the lower end of PCI values, there is a notable difference. In the manual-based calculations, estimators may have committed some errors in estimating the severity of pavement distresses. This may have been the result of recent experience with this rating procedure. In future inspections, one would expect that inspectors would be more consistent as they develop the required expertise and precision. This observation was also noted by other researchers who acknowledged the human errors in the determination of pavement distress types and the associated severity [10]. The comparison of PCI values obtained from manual calculations is compared to those obtained from Micro PAVER 7 reports are depicted in Fig. 5. In General, there is an agreement but with slight discrepancies.

Table 1. Summary of PCI Calculations.

| PCI Rating | Manual PCI Calculation | | PCI as Calculated by Micro PAVER 7 | |
|---|---|---|---|---|
| | No. of sections | % | No. of sections | % |
| Good | 1 | 2.2 | 1 | 2.2 |
| Satisfactory | 4 | 8.9 | 4 | 8.9 |
| Fair | 4 | 8.9 | 4 | 8.9 |
| Poor | 7 | 15.6 | 7 | 15.6 |
| Very Poor | 17 | 37.7 | 14 | 31.1 |
| Serious | 12 | 26.7 | 11 | 24.4 |
| Failed | 0 | 0.0 | 4 | 8.9 |
| Total | 45 | 100 | 45 | 100 |

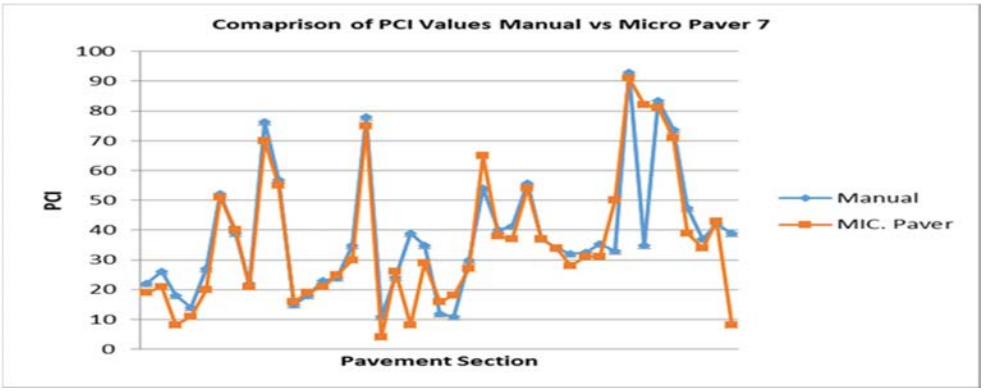



Fig. 5. The PCI Comparison.

Table 2 represents a preliminary summary of pavement distress quantities in the network which can be used to estimate the M&R priorities and costs.

Table 2. Summary of Pavement Distress Quantities Based on Initial Inspection.

| Distress Type | Severity Level | Measurement Unit | Quantity |
|---|---|---|---|
| Alligator Cracking | High | $m^2$ | 430.5 |
| | Medium | $m^2$ | 528.6 |
| | Low | $m^2$ | 223.8 |
| Block Cracking | High | $m^2$ | 464.2 |
| | Medium | $m^2$ | 2136.2 |
| Bumps and Sags | High | m | 11.3 |
| Depression | High | $m^2$ | 206.8 |
| | Medium | $m^2$ | 673.2 |
| | Low | $m^2$ | 1.76 |
| Edge Cracking | High | m | 2.5 |
| | Medium | m | 115.6 |
| Longitudinal and Transverse Cracking | High | m | 1154.2 |
| | Medium | m | 3950.0 |
| | Low | m | 498.8 |
| Patching and Utility Cut | High | $m^2$ | 776.2 |
| | Medium | $m^2$ | 4618.1 |
| | Low | $m^2$ | 14.6 |
| Potholes | High | No. | 44 |
| | Medium | No. | 130 |
| | Low | No. | 73 |
| | Medium | $m^2$ | 239.2 |
| | Low | $m^2$ | 461.4 |
| Slippage Cracking | High | $m^2$ | 9.6 |
| | Medium | $m^2$ | 26.1 |
| | Medium | $m^2$ | 66 |
| Weathering and Raveling | High | $m^2$ | 231 |
| | Medium | $m^2$ | 224.3 |
| | Low | $m^2$ | 495.2 |

The results of the field inspection and the calculations of PCI values for each pavement section are represented in Fig. 6. The coloring scheme is consistent with coloring scheme used by the developers of Micro PAVER 7 to show the condition of each pavement section according to the seven PCI levels shown in Fig. 3.


Fig. 6. Road Sections and Sample Units Definitions and Condition Evaluation.

## 7. Conclusions and Recommendations

The research will contribute to provide a systematic method to manage the M&R process of the pavement network. Although, many researchers in Jordan dealt with procedures for M&R of road networks, there is still lack for systematic strategy and prediction procedure. This research will help to provide a model to be adopted by other organizations in Jordan.

During the implementation and application of the PMMS in this study, some challenges were observed. The challenges included the unavailability of historical maintenance records on some sections within the network. In certain instances, it was extremely difficult to verify the available pavement structure layer thicknesses. This would require the need to investigate by trenching techniques or by taking cores of pavements to identify the pavement composition and thicknesses in some areas. Moreover, the application of the new PMMS needs time and effort to implement the new procedures and it requires knowledge and training on the utilization of applicable computer programs.

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