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Development of a Management System for Paved Assets

Wael Bekheet[1]
[1]*Faculty of Engineering, Alexandria University El-Horreya Ave., El- Hadarra, Alexandria, Egypt, 21544*
Phone: +2 (03) 544-0377 Fax: +2 (03) 542-5017

Abstract:- Large enterprises have a significant percentage of their maintenance budgets directed towards maintenance of paved assets. They need to maintain these assets at an acceptable level of service in terms of both functional condition and level of safety.
Typical pavement management systems are tailored towards continuous roads or defined road networks. However, depending on the conditions of each enterprise, some of their paved assets can be difficult to include in a typical pavement management system, since these assets represented individual pavement sections that are significantly different from a traditional road from functional and geometric perspectives.
This paper presents an approach to customize typical pavement management tools to manage an enterprise paved assets, using the paved assets managed by a school board as a case study. The paved assets were divided into sections, and field condition survey was carried out to assess their current condition. Analysis models were then developed based on experience and finalized through a cycle of preliminary pavement management analysis and ground truth visits, by a panel of experts, for models validation.
The approach presented in this paper showed the potential use of existing analysis tools to manage paved assets within the framework of an asset management system.

Keywords:- Pavement Management, Asset Management, Paved Assets, Condition Assessment, Pavement Performance

I. INTRODUCTION

Large public or private agencies or enterprises, such as school boards, chain stores, and public utilities companies that have a number of different asset types, tend to overlook paved assets, such as parking or storage areas, even though a significant capital and maintenance budgets are directed towards these paved assets.
Managing the paved assets of such enterprises using a typical pavement management system might represent a technical challenge. Paved assets in these cases are significantly different from a traditional road network from functional and geometric perspectives. Traditional pavement management tools are typically geared towards continuous road networks. However, for other discontinuous paved assets, such as parking areas, loading/unloading zones, schools playgrounds, these tools might require significant customization to effectively manage such assets [1].

In this paper, an approach to develop a pavement management system to manage a discontinuous network of paved assets is presented. As a case study, a management system for managing the paved assets of a typical school board is developed. School boards are one example, where there is a need to maintain these assets at an acceptable level of service in terms of both functional condition and safety level.

Due to the special nature of a disconnected network of paved assets and the lack of historic data that can be used to develop the analysis models in the system, all analysis models were generated based on experience and discussions with maintenance engineers from the schools. These models were then adjusted and finalized through a cycle of preliminary pavement management analyses, ground truth visits, and fine tuning of the analysis models [2].

The research presented in this paper involved the network definition, inventory, condition assessment, and models development. The network definition involved functional sectioning the paved assets, while the condition assessments were carried out using a visual distress survey. The condition index was based on the US Corps of Engineers Pavement Condition Index (PCI) [3], but modified to fit the functional conditions and safety requirements of the paved assets considered in the study.

Once the system/network was assessed, all the collected data was loaded into a commercially available pavement management system database. The implementation involved the development of a set of analysis models including deduct values for a modified PCI, Maintenance and Rehabilitation (M&R) decision tree, and performance prediction models. Each of these models required special customization to address the specific nature of the assets included in the analysis.

It should be noted that although the research presented in this paper used the paved assets of a typical school board as a case study, the same approach can be applied to any enter large public or private agencies or enterprises with paved assets.

II. NETWORK DESCRIPTION

Fig. 1 shows the layout of a typical school and how the paved areas were divided into different sections based on the functional classification. These discrete sections were then used for inspection, data collection and inclusion in the pavement management analysis. The typical school property generally consisted of a number of unique components or sections. These sections were identified as heavy traffic (HT) areas, parking lots (PL), play areas (PA), soft surfaces (SS), and sidewalks (SW).

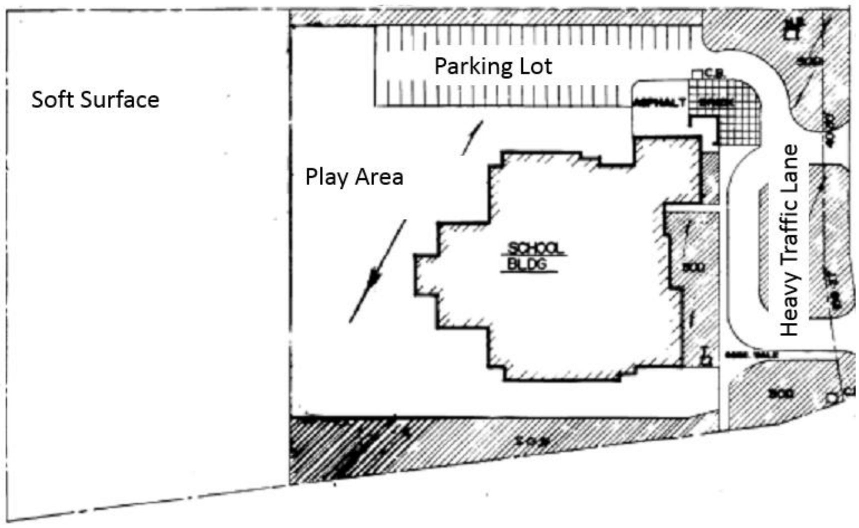

Fig.1: Functional Classification of Typical School

HT sections received frequent heavy vehicle traffic such as school busses, delivery vehicles, or garbage trucks. These sections are generally located to the front of the schools and often included a bus loop. PL sections are parking facilities, where school staff or students (high schools) would park their cars while accessing the facility.

PA sections are the paved areas used by students during lunch or recess. These sections are typically located at the back or on the perimeter of the school. In some case, play areas were subjected to heavy vehicle traffic including delivery or maintenance vehicles, and garbage trucks. SS sections were sodded or grassed areas used during lunch or recess as play areas and often included soccer fields, and football fields. SW sections included any sidewalk used by staff or students to access a property or a building that was located on school property.

In this study, only paved sections – HT, PL, and PA – were considered in the pavement management system. In total 390 paved assets were included in the study distributed over 100 sites managed by one school board.

III. CONDITION ASSESSMENT

The objective of the condition assessment was to inventory and assess the condition of the existing paved assets, as well as other assets such as curbs, sidewalks, and manholes. The condition assessment of the paved assets included the field condition survey and the customization of the Pavement Condition Index (PCI) to quantify the pavement condition.

A. Condition Survey

Each pavement section was assessed through a visual distress survey, using a distress rating methodology generally consistent with ASTM D6433 [4] distress rating methodology, which is a widely used criteria for evaluating pavement distresses. The extent and severity of each distress type was measured and logged. The extent and severity levels for each distress type for asphalt concrete pavements considered in the survey are presented in Table 1.

Table 1 Asphalt Concrete Pavements Distress Types

ID	Distress Type	Unit	Levels of Severity
1	Linear Cracking	m	3
2	Alligator Cracking	m^2	3
3	Edge Cracking	m	3
4	Map Cracking	m^2	3
5	Pot Holes	count	1
6	Raveling	% area	3
7	Bleeding	%	3
8	Distortion	m^2	3
9	Rutting	m	3
10	Patching	m^2	1

As can be noted from the tables, not all the standard distresses described in the ASTM D6433 standard were considered. Only the distresses relevant to the paved assets under consideration were considered in the survey. Some distresses, such as the slippage cracking, joint reflective cracking and lane/shoulder drop off were not considered in the analysis, since they did not apply to the conditions of the paved assets under consideration. In addition to pavement distresses, various drainage items and associated distress were logged such as the number of catch basins, settlement at catch basins, the relative elevation of the surface to the adjacent grade, and if any blockage was observed at a catch basin. These items were logged for inventory reasons, but not considered in the paved assets management analysis.

B. Development of the Pavement Condition Index (PCI)

The Pavement Condition Index (PCI) was used to identify the overall pavement condition for each section. The original PCI model was developed by the US Corps of Engineers [3] and it is a deduct value model. The index is defined on a scale of 0 to 100, where at 100 the pavement was assumed to be in perfect condition. In using this index, a pavement sections is assumed to be in a perfect condition with a PCI of 100 and then deduct values are subtracted for each observed distress, depending on the type, severity and extent of the distress. Deduct values are used to provide the weightings indicating the relative importance of the distresses/severity levels in terms of the pavement condition.

The PCI in this study was calculated based on the original PCI approach, but with some customization to adequately address the condition of the paved assets in this study. Deduct value for each distress type / severity level combination was adjusted from the original PCI to reflect the relative importance of distresses in terms of the safety of the school system. As an example, the deduct values for distortion was increased relative to traditional models, since this type of distress represents a tripping hazard for students. Also, any type of distress that would result in the pavement disintegration, such as high severity alligator cracking, was assigned a higher deduct value.

The deduct value for each distress type / severity level combination were then validated using field data through the ground truth visits [5].

C. Overall Condition

In total, 390 paved sections were considered in the analysis. The average PCI value for the 390 pavement sections - comprised of the three functional classification areas HT, PL, and PA - was found to be 69.5 with a standard deviation of 27.5. Of the 390 sections, 47% were found to have a PCI value greater than 80, generally identified to be in good to excellent condition, and approximately 31% were found to have a PCI value less than 60, generally described to be in poor to very poor condition.

Fig. 2 shows the distribution of PCI for each of the three paved assets types considered in the study. As can be noted from the figure, HT sections seem to have a worse condition distribution than the other paved assets types, with 36% of the sections with PCI values less than 60, while the PL and PA sections have 29% and 30% of the sections with PCI values less than 60, respectively. This is expected given the traffic loading conditions of the HT sections compared to the PA and PL sections.

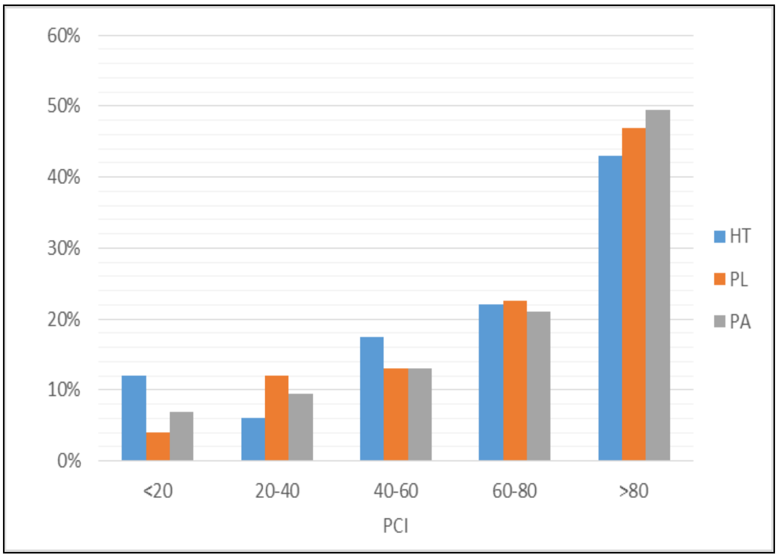

Fig.2: PCI Distribution for All Paved Sections

IV. PAVEMENT MANAGEMENT ANALYSIS MODELS

Given the lack of any historic data for the sections considered in the analysis and due to the fact that the paved assets considered in this study were different from a traditional road from functional and geometric perspectives. The development of the analysis models needed for the pavement management analysis were set based on the collected data and experience [2]. These models were then validated and adjusted based on the ground truth visits [5]. The models included M&R decision trees, and performance prediction models

A. Decision Tree

The decision trees are used in pavement management analysis to select feasible rehabilitation alternatives from a set of M&R activities. These activities were selected as a generic set of activities that can be used on paved assets [6]. Fig. 3 shows the decision tree used in this study. The decision tree is based on the pavement condition and the functional classification of the pavement section.
The condition levels used in the tree were based on field observations and typical actions taken by the maintenance engineers in the schools, as compared to the pavement condition at the time of the maintenance and/or rehabilitation of a pavement section. The decision tree was validated during ground truth visits and discussions with maintenance engineers.

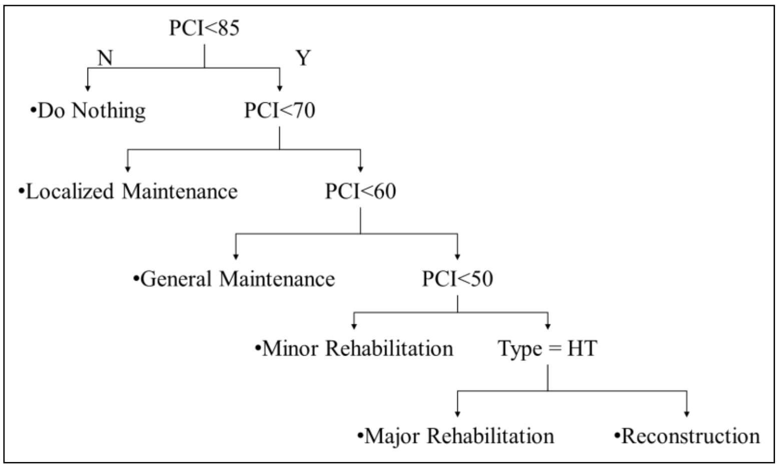

Fig.3: Decision Trees

B. Performance Prediction Models

Performance prediction models are a key component of any PMS. They are used to predict future performance of a pavement section, which is used to identify future pavement rehabilitation needs and future condition [7].

Models were developed based on expected service lives, by functional classification, for each M&R activity. The prediction models used in the system were deterministic models. The service lives for various M&R activities were defined based on experience from similar networks and discussions with maintenance engineers [5, 8]. Fig. 4 shows an example of the performance prediction models used in the study.

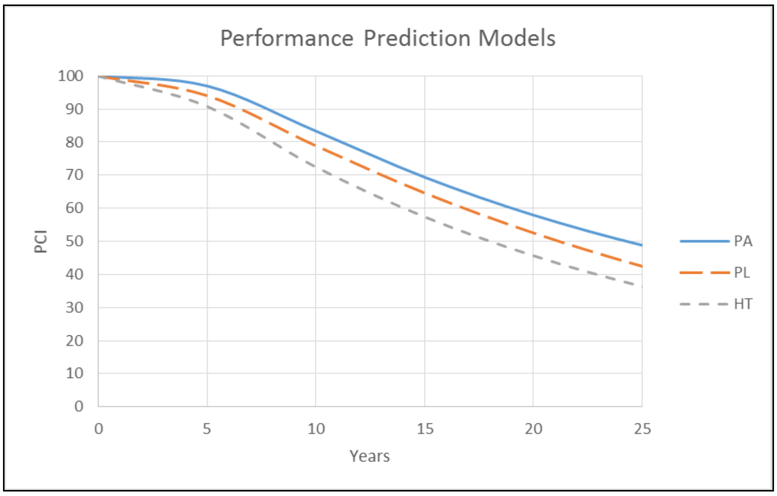

Fig. 4: Index Prediction Models

The models shown in the figure are for reconstruction activities. However, models for other activities were generated in a similar manner. The models were validated through ground truth visits based on the approximate ages of the pavement sections considered in the study [5].

V. GROUND TRUTH VISITS AND PAVEMENT MANAGEMENT ANALYSIS

Due to the special nature of a disconnected network of paved assets, such as that of a large public of private enterprise, the implementation of the pavement management system is a challenge, as the paved assets were significantly different from a traditional road network. In addition, in many cases, the available historic data that can be used to develop the analysis models in the system is limited. In the case study considered in this research, no historic data was available for the paved assets that can help generate the analysis models described in the previous section. As a result, all these models were generated based on experience and discussions with maintenance staff of the schools.

To validate these models, a cycle of preliminary pavement management analyses, ground truth visits, and fine tuning of the analysis models were carried out. The models that required validation were the PCI model, M&R decision trees, and performance prediction models.

Using a preliminary set of models, a pavement management analysis was carried out at the section level and a number of candidate sections were selected for field validation. These sections were then visited for ground truthing by a panel of experts to validate the models and adjust them.

Ground truth visits included a panel of experts from maintenance staff and experienced personnel. In total 27 pavement section distributed over 10 sites were visited and analysed for this validation. During these visits, the analysis results of each section were compared against the actual field conditions and the expectations of the panel for the pavement condition of each section.

The deduct values used for the PCI model were adjusted based on the discussions during the ground truth visits. The deduct values were adjusted to increase or decrease the impact of individual distresses, such that the calculated PCI would match, as much as possible, the expected PCI by the panel. Fig. 5 shows the calculated PCI values versus the PCI values estimated by the panel after finalization of the PCI model. As can be noted from the figure, the correlation between the calculated PCI value and the estimated value by the ground truth panel was high with a coefficient of determination of 92.5%

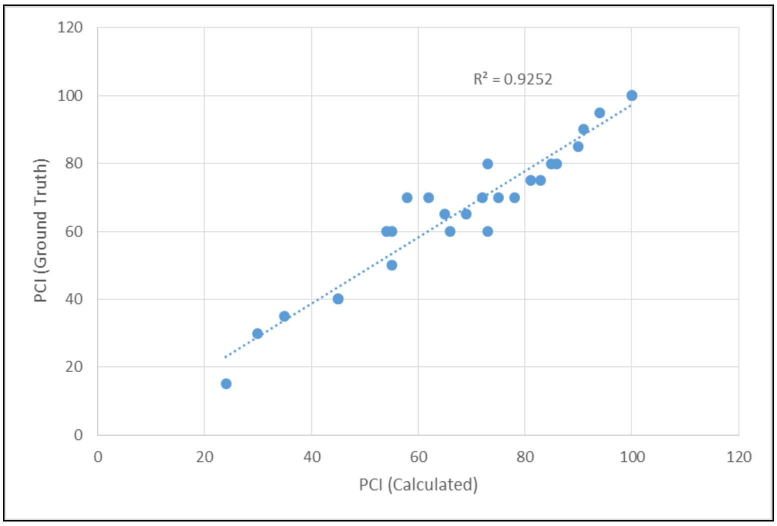

Fig. 5: PCI Ground Truth Results

Decision trees were validate in a similar manner during these visits based on the panel's opinion on how a paved section should be maintained or rehabilitated depending on its current conditions. The modifications to the decision trees had the objective of mirroring the decision process of the panel, such that the maintenance or rehabilitation decision generated by the final decision trees would be as close as possible to the decision taken by the panel of experts

The performance prediction models were adjusted in a manner similar to the decision trees. However, the models were adjusted in terms of service lives and the approximate age of different sections at the time of the visits. Due to the absence of reliable historic data, the amount of data used to validate the performance models was generally limited.

The main objective of the pavement management analysis at this stage of the study was to validate the analysis models and fine tune the system and to identifying the current network condition and needs. As this objective was met after the finalization of the pavement management models, the system was deemed ready to be used for long term analysis to identify future network needs and to optimize the forecasted future budget.

VI. SUMMARY

This paper presents an application of typical pavement management tools to manage a unique network of disconnected paved assets. The implementation of the system was a particular challenge, since the paved assets represented individual pavement sections with no historic performance data, and were significantly different from a traditional road from functional and geometric perspectives.

The paved assets were divided into specific pavement sections for condition assessment and field survey. Once the sections were assessed, all the collected data was loaded into a commercially available management system database. The analysis models were developed based on experience and modified to fit the special conditions of the pavement network under consideration.

The analysis models, including the condition index, M&R decision trees and performance prediction models, were finalized through a cycle of preliminary pavement management analysis and ground truth visits for models validation. The ground truth visits were carried out by a panel of experts. The pavement management analyses results using the models adjusted after these visits showed reasonable results in terms of current pavement condition and expected future performance.

The development of the paved asset management system was successful, and the approach presented in this paper showed the potential use of existing analysis tools to manage paved assets within the framework of an asset management system.

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