Modeling the Methods of Flexible Pavements Maintenance

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Abstract: This paper describes the development of Evaluation of Pavement Condition Model software (EPCM), which consists of three main elements. The first element deals with a road network definition to create a database for each road in the network to make future predictions of pavement condition. The second element evaluates the present status of asphalt pavement depending on the type, severity, and extent of distress, and then calculates the value of a pavement condition index. For each value there is certain pavement condition requiring one type of maintenance activity. The third element deals with prediction of the pavement condition in future. This element cannot be applied in Iraq now because there are no historical data for each road in the network, but after applying this model and saving the information about each road, this will become possible after drawing a curve for each asphalt pavement. The written software was applied to a case study of local road in Abo-Ghreeb city in Baghdad with a length of 1.45 km and a width of 8 m. The result of this application was that road required an asphalt overlay. According to the Abo-Ghreeb municipality, the required maintenance activity for this road was resurfacing, which is the common maintenance method in Iraq. This is different because of the independency on a fixed criterion to select a maintenance method. **DOI: 10.1061/(ASCE)TE.1943-5436.0000479.**

Author keywords: Evaluation; Flexible pavement; Highways; Maintenance; Management; Pavement; Pavement condition index; Roadways; Transportation engineering.

Introduction

Distress is defined as a condition of a pavement structure that reduces serviceability or leads to a reduction in serviceability. Serviceability is defined as the ability of pavement to provide a safe and comfortable ride to its users (Johanns and Craig 2002). Flexible pavement surface distresses include a wide variety of pavement defects that generally fall into the following categories (Garber and Hoel 2009):

1. Cracking
   - Alligator
   - Edge
   - Longitudinal
   - Random/block
   - Transverse
2. Raveling/weathering
3. Distortion
4. Rutting
5. Excess asphalt

Previous Studies of Pavement Maintenance in Iraq

Daoud (1997) developed a maintenance management system of highways in Iraq. The research used the background of the existing state of the highway network and on the conditions of the existing maintenance management system of the State Corporation for Roads and Bridges for highways. Through the search of the previous policies and procedures, the analysis of the existing system showed that several major deficiencies exist.

Ajam (1999) developed an expert system, which contains a knowledge base of heuristic rules about types, causes, and remedies of distresses occuring in flexible pavement. In this thesis, the knowledge is extracted from the two previously mentioned knowledge sources, which contain information from questionnaires and interviews with senior pavement engineers (experts), who have expertise in flexible pavement engineering. This information was entered in to an expert system builder shell called "CRYSTAL."

Mohammed (2001) developed an expert system to control highway maintenance problems, "HMPCES," where the domain of highway maintenance and rehabilitation has been selected with the purpose of defining standards (controlling the activity problems). The research includes flexible pavement problems, drainage problems, roadside problems, and miscellaneous problems and selects the suitable maintenance activity depending on the severity of distress in flexible pavement and the type of problem in other cases. The developed system is based on information from text books, papers, manuals, journals, and interviews with senior pavement engineering (experts), especially in road maintenance. This system is considered a practical tool that helps engineers to select the suitable and correct maintenance activity for different highway problems.

Geiger (2005) reported that pavement preservation represents a proactive approach in maintaining existing highways. It enables state transportation agencies to reduce costly, time-consuming rehabilitation and reconstruction projects and the associated traffic disruptions. With timely preservation, the traveling public can be provided with improved safety and mobility, reduced congestion, and smoother, longer-lasting pavements. A pavement preservation program consists primarily of three components: preventive maintenance, minor rehabilitation (nonstructural), and some routine maintenance activities.

Jaber (2007) developed an optimization model capable of selecting the optimum set of projects from the network, taking into consideration budget constraints and the achievement of multiple

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Note. This manuscript was submitted on October 3, 2011; approved on June 24, 2013; published online on June 26, 2013. Discussion period open until May 5, 2014; separate discussions must be submitted for individual papers. This paper is part of the ***Journal of Transportation Engineering***, © ASCE, ISSN 0733-947X/04013014(5)/$25.00.

objectives. The performance of the network with different budget scenarios and different objectives was studied.

The study includes the environmental impact of maintenance decisions. In other words, the model tries to select maintenance alternatives that would result in minimum emission levels. The study also is extended to identify the links to be maintained under each activity type. This study utilizes a goal programming technique to optimally allocate funds for highway maintenance activities.

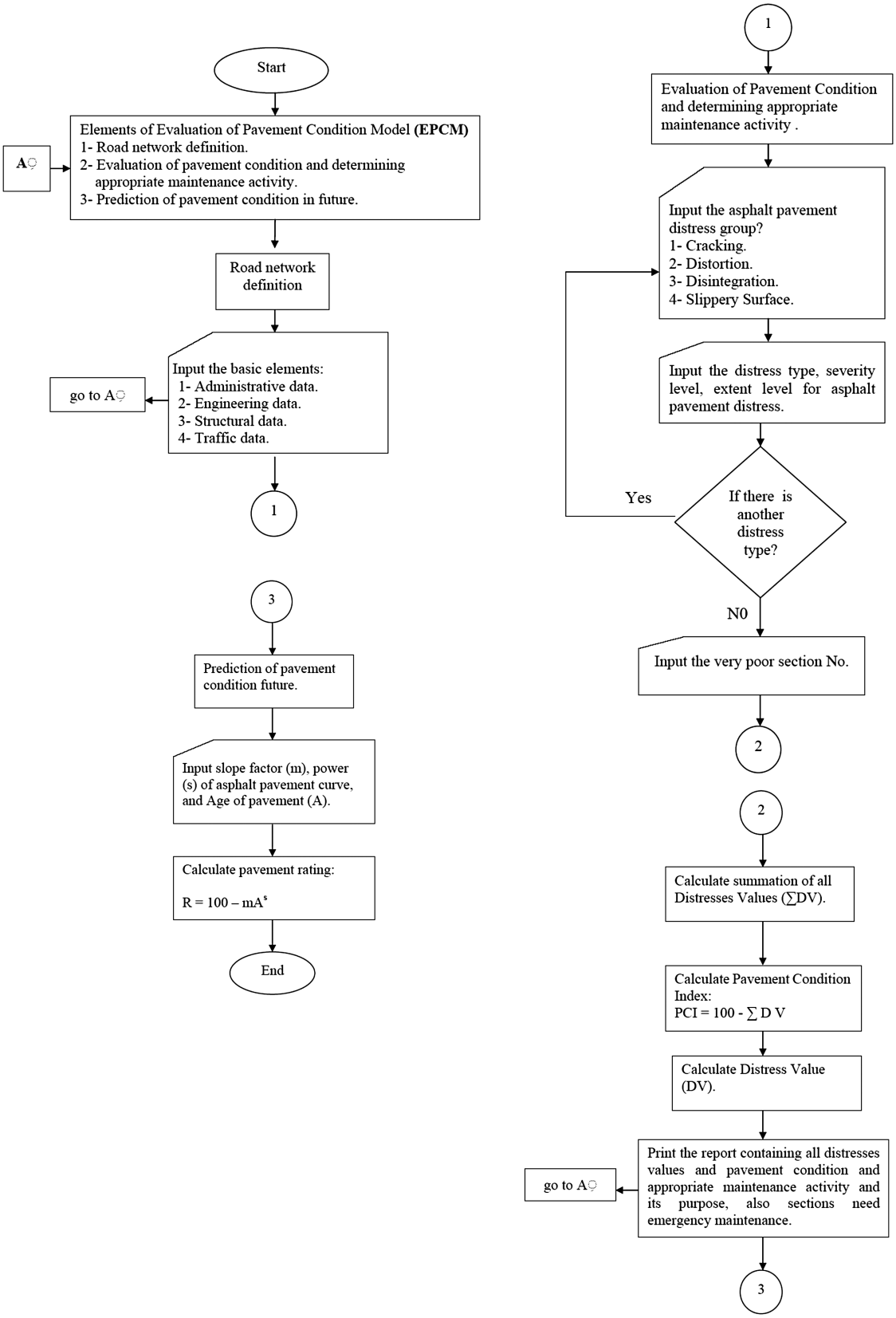

Fig. 1. Flowchart of ECPM software

Evaluation of Pavement Condition

Evaluation of pavement condition is modeled by using visual basic language in software called the Evaluation of Pavement Condition Model (EPCM). Fig. 1 shows the flowchart for this software. The following sections describe the details of the programming of each component of the developed evaluation model.

Elements of EPCM Software

The main form of EPCM shows the three main elements of the proposed model: (1) networks definition, (2) evaluation of pavement condition and determination of the appropriate maintenance activity, and (3) prediction of pavement condition in future. Any element considered is a very important part of the EPCM software.

Road Networks Definition

The network definition consists of four main elements needed to define the road network:

- Administrative data consisting of the following: road type, road name, road number, and road location;
- Engineering data, including measurements of road length, road width, number of lanes, and number of sections;
- Structural data, including pavement type, construction date, last maintenance date, and type of last maintenance activity; and
- Traffic data, including average daily traffic (ADT) and the percentage of trucks.

This information is very important and necessary to make a suitable database for all roads in Iraq to allow workers in the field to easy access the required information about certain roads.

Evaluation of Pavement Condition and Determining Appropriate Maintenance Activity

Four main distress groups occur in asphalt pavements (cracking, distortion, disintegration, and slippery surfaces), and each of them include secondary types. Cracking, for example, has five subtypes addressed in this research (alligator, slippage, shrinkage, longitudinal, and transverse). Also, distortion consists of three subtypes (rutting, depression, and corrugation).

Potholes and raveling act the disintegration failures. Bleeding and the presence of a polished surface act the widespread slippage surface problems in Iraq. This model asks if there is an additional distress type after the user enters an initial distress type. The EPCM software divides paved road into several sections with length of 100 m for each section. The purpose of this step is to get the best results of maintenance for road pavement, because the model asks about the abundance of severe failure or complex damage within specific sections to make special decisions about each section in addition to maintenance decisions for the entire road after entering all distress types.

The proposal model for evaluating the state of pavement was based entirely on measurements of the status of surface damage, which is considered a main criterion to indicate the need for maintenance and serves to accurately identify the type of maintenance required.

By this, the measure of skid resistance has been excluded because it is not considered a reliable expression of the road condition. Also, the measure of servicing regularity was ruled out because of the relationship to cost of operation and because no adequate information is currently available, as planning activities at the network level are not known.

Limiting the Severity and Extent Levels

For the purpose of developing classes for observed damage, the severity for each type of damage has been divided into five levels (slight, low, moderate, high, and very high), as used in many systems worldwide. The severity and extent levels of damage are converted to a numerical value that is included in the calculation of pavement condition index (PCI) after calculating distress value for each distress type by multiplying the severity factor (Fs) by extent factor (FE) by the weight value of this distress (W), as given by Shahin and Kohn (1982)

$$\mathrm{DV} = \mathrm{Fs} \times \mathrm{FE} \times W \tag{1}$$

These factors are shown in Table 1, and weight values are shown in Table 2. The summation of all calculated distress values are used to calculate the pavement condition index. Pavement condition index is calculated by Eq. (2), as given by Shahin and Kohn (1982)

$$\mathrm{PCI} = 100 - \Sigma\mathrm{DV} \tag{2}$$

Depending on the value of PCI, the required maintenance activity and its purpose can be determined.

Prediction of Pavement Condition in the Future

The pavement rating R can be calculated by using Eq. (3)

$$R = 100 - mA^s \tag{3}$$

where m = slope factor; S = power of asphalt pavement curve; and A = age of road pavement.

Prediction of pavement condition for roads in Iraq required historical data for each road to know the behavior of the asphalt pavement curve; this data was classified depending on the road type and the pavement type.

Table 1. Severity and Extent Factors of EPCM

Severity level	Fs	Extent level	FE
Slight severity level	0.3	Slight extent level	0.3
Low severity level	0.5	Low extent level	0.5
Moderate severity level	0.7	Moderate extent level	0.7
High severity level	0.9	High extent level	0.9
Very high severity level	1.0	Very high extent level	1.0

Table 2. Weight Values of Distress

Distress type	Weight value
Alligator crack	10
Longitudinal crack	5
Slippage crack	5
Transverse crack	5
Shrinkage crack	5
Bleeding	10
Polished surface	10
Raveling	10
Potholes	10
Rutting	10
Corrugation	10
Depression	10

Then this provides the readings, which can found its relating equation by slope method and this act the serviceability curve specific with the road and pavement type.

The process of periodically viewing roads behavior data over time after each maintenance activity allows the model to predict pavement condition and whether it should be left without maintenance or treated by a certain maintenance activity.

Case Study

A demonstration from EPCM gives a practical example for the initial model use and the model logic, as it is illustrated in the case study. The case study is a local, undivided, 2-lane, 2-way road named Al- Amaraat Street that begins in the Said Sachet district and ends in the Al- Amaraat district, with a length of 1.45 km and width of 8 m. This road was constructed in 1980; therefore, many types of distresses have occurred in this road with different severity and extent levels. Table 3 shows the summary of results obtained using EPCM software. All information about this road was taken from Abo-Ghreeb municipality.

By applying Eq. (2), the PCI is computed as

$$\mathrm{PCI} = 100 - 45.7 = 54.3 \tag{4}$$

According to this value, the pavement condition is fair and required an asphalt overlay.

Road Network Definition of the Case Study

This element includes inputs of administrative, engineering, structural, and traffic data from the case study, shown in Table 4.

Table 3. Summary of Results Obtained Using EPCM Software

Distress type	Fs	FE	W	DV = Fs × FE × W
Alligator cracks	1.0	0.9	10	9
Longitudinal cracks	0.9	0.9	5	4.05
Transverse cracks	0.7	0.9	5	3.15
Depression	0.9	0.9	10	8.1
Corrugation	0.9	0.7	10	6.3
Potholes	1.0	0.7	10	7
Raveling	1.0	1.0	10	8.1
Total				45.7

Table 4. Inputs of First Element of EPCM for the Case Study

Item	Description
Administrative data	
Road type	Local road
Road name	Al- Amaraat Street
Road number	Not found
Road location	Abo- Ghreeb city
Engineering data	
Road length	1.45 km
Road width	8 m
Number of lanes	two
Number of sections	14
Structural data	
Pavement type	Flexible pavement
Construction date	1980
Last maintenance date	—
Type of last maintenance activity	Not found
Traffic data	
Average daily traffic	28,000
Truck percentage ratio	5%

The average daily traffic of this case study exceeds the limits of ADT for local roads because of the closing of other roads. The inputs of this element are described next.

Evaluation of Pavement Condition of Case Study

The second step of EPCM software includes the inputs of distress types. Severity and extent levels of these distresses are shown in Table 5. All these elements are required to select the required maintenance activity, which is dependent on the value of the pavement condition index.

Fig. 2 shows the road report of the case study, which includes all information about road definition (administrative, engineering, structural, and traffic data). It also includes computation of distress values that occur in case study, in addition to pavement condition, required maintenance activity, its purpose, and the number of sections that required special treatments.

The supervisior maintenance engineers on this road decided that resurfacing was the suitable maintenance activity, but the EPCM software chose asphalt overlay as the required maintenance activity after limiting severity and extent levels of distress.

Table 5. Distress Types of Case Study

Distress type	Severity level	Extent level
Alligator cracks	Very high	High
Longitudinal cracks	High	High
Transverse cracks	Moderate	High
Depression	High	High
Corrugation	High	Moderate
Potholes	Very high	Moderate
Raveling	High	High

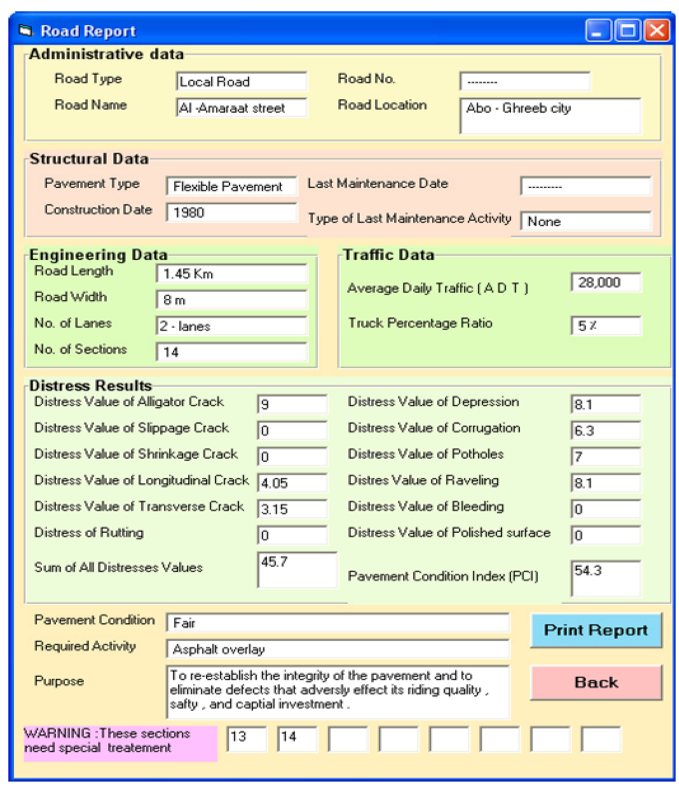

Fig. 2. Road report for the case study

Prediction of Pavement Condition in Future of Case Study

The third element of EPCM software was not applied to this case study because there was not enough historical data about this road to draw a pavement curve to calculate pavement rating (R) by using Eq. (3).

Conclusions

The conclusions drawn from this work can be summarized as follows:

- Iraqi roads do not receive an effective and proper maintenance during their service life until they reach the state of major failure that requires rehabilitation.
- Preventive maintenance is excluded from the maintenance policy adopted by Iraqi road authorities.
- Despite the proper control and effects required for maintenance, which is considered a dynamic process, there is a lack of qualified maintenance engineers working in road directorates in each governorate.
- There is a lack of control over the load limit carried by vehicles, and the lack of weighing stations enable truck drivers to overload their trucks with more than the permitted loads. If such conditions continue, the maintenance system will fail to achieve its objective, and great damages and losses in resources including investments will occur.
- Machines and equipment allocated for maintenance works are not enough and not capable of performing the required jobs. In addition, there is a lack of the required number of equipment in repair workshops and a severe shortage in the required spare parts for these repair shops.
- There is shortage of training courses and lack of information gathering about practices and experience of other countries regarding both managerial and technical matters of highway maintenance.
- Mismanagement of maintenance activities leads to delays and accumulation of failures in the highway network, which lead to unusual expenditures to repair the accumulated damages and maintain roads well.
- There are shortages in resources allocated for maintenance works, and this leads to the diversion of significant portion of the allocated fund for maintenance works toward purchasing of new or additional equipment to be used for the construction of new roads.
- The developed software EPCM is written by using visual basic language and can evaluate pavement condition, determine the most appropriate maintenance activity, and predict pavement condition in the future.
- The EPCM software contains 27 forms; each one includes the inputs of each element of asphalt pavement and supplies the user with the option of eliminating any element if the user cannot get the required information for calculating it.
- The EPCM software was applied successfully to a local road in Abo-Ghreeb city, resulting in asphalt overlay as the required maintenance activity.

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