Anticipation Methods for Forecasting Pavement Condition Index

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Abstract

Pavements are complex structures involving many variables, such as materials, construction, loads, environment, performance, maintenance, and economics. The road network requires great care through conducting periodic evaluation and timely maintenance to keep the network operating under acceptable level of service. Maintenance is an essential practice in providing for the long-term performance and the esthetic appearance of pavement. Thus, development of Pavement management system is necessary to determine the current condition of a road network and predict its future condition. Pavement management consists of Monitoring Post-construction condition, timing preventive maintenance and rehabilitation treatments, and economic analysis of alternatives. Pavement management system is a set of defined procedures for collecting, analyzing, maintaining, and reporting pavement data, to assist the decision makers in finding optimum strategies for maintaining pavements in serviceable condition over a given period of time for the least cost. The purpose of this paper is to review is to review all alternative methods for forecasting PCI using different approaches like ASTM method, MicroPAVER, artificial neural network, genetic programming, evaluation of pavement condition model (EPCM) software. With the help of these index we can recognize pavement surface defects and understand their causes, helps us to rate pavement condition and select cost-effective repairs. Periodic inspection is necessary to provide current and useful evaluation data. The purpose of pavement maintenance is to correct deficiencies caused by distresses and to protect the pavement from further damage. A condition rating of the pavement will help to determine what pavement maintenance technique is necessary.

KEYWORDS - Pavement distresses, pavement condition index, MicroPAVER evaluation of pavement condition model (EPCM), artificial neural network, genetic programming.

I. Introduction

Various technical and economic factors must be well understood to design pavements, to build pavements, and to maintain better pavements. Moreover, the problems relating to road maintenance are still more complex. Thus, there is a need to apply a scientific approach to manage the maintenance of the road network effectively. And the assessment of pavement conditions has become an integral part of the pavement management system

(PMS). There are currently several indices that are used to describe pavement conditions, such as the pavement condition index (PCI), present serviceability index (PSI), international roughness index (IRI), and present serviceability rating (PSR). All of these indices convert pavement distresses to a more practical index. The PCI is one of the most common indices for pavement evaluation. (Habib shahnazari 2012).

The Pavement Condition Index rates the condition of the surface of a road network. It measures two conditions: The type, extent and severity of pavement surface distresses (typically cracks and rutting), and the smoothness and ride comfort of the road. The PCI is a subjective method of evaluation based on inspection and observation. It provides a numerical rating for the condition of road segments within the road network, where 0 is the worst possible condition and 100 is the best.. The PCI should be conducted annually so that changes in road condition can be evaluated. The PCI tells public works officials the current condition of the road network, and the rate of deterioration of the road network over time. A PCI is used to Identify immediate maintenance and rehabilitation needs, Monitor pavement condition over time, Develop a network preventive maintenance strategy, Develop road maintenance budgets, and Evaluate pavement materials and designs. However, many difficulties are associated with the measurements and precise estimations of the inputs involved in the pavement condition index distress models.

In this direction, soft computing techniques like ASTM method, Micropaver method, artificial neural network, genetic programming, EPCM method has demonstrated to be particularly appropriate for such types of predictions.

II. Methodology

Methodology of this study consists of procedures for forecasting PCI using different approaches like ASTM method, MicroPAVER, artificial neural network, genetic programming, evaluation of pavement condition model (EPCM) software

Shahin and kohn(1981)

Calculation of PCI for asphalt pavement(AC) can be summerized by following steps

- Divide each branch into sections based on the pavement design, construction history, traffic, and condition, and the pavement sections into sample units.
- Determine total Severities of each distress type at each severity level (low, medium, high) by adding up total quantities of each sample unit.
- Determine percent density of each distress type and severity by dividing the total quantity by the total area of the sample unit.
- Determine the deduct value (DV) for each distress type and severity level from the distress deduct value curves. Typical deduct value curve for alligator cracking is shown in the figure1.
- Determine maximum CDV to determining the PCI. To determine maximum CDV arrange individual deduct values in descending order, Determine the allowable number of deducts, m, from using Eq 1

$$m = 1 + \left(\frac{9}{98}\right)(100 - HDV) \leq 10 \qquad \text{Eq. 1}$$

- The number of individual deduct values is reduced to the m largest deduct values, including the fractional part. Determine total deduct value (TDV) by adding individual deduct values, Determine q as the number of deducts with a value greater than 2.
- Determine the CDV from total deduct value and q by looking up the appropriate correction curve.
- PCI is calculated by subtracting the maximum CDV from 100.

  PCI = 100-max CDV.

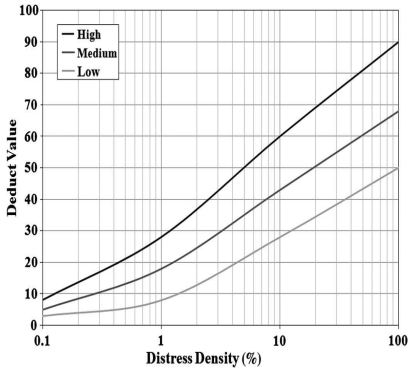

Fig.1. Typical deduct value curve (data from Shahin 2005)

MicroPAVER method

Divide each branch into sections and pavement sections into sample units. Enter inspection information about branch, section, sample units, date of inspection, distress type and severity level of each sample unit. Software describing MicroPAVER methodology is shown in figure 2.

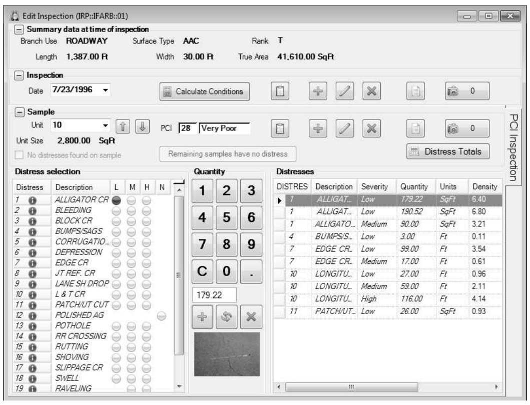

Fig.2. MicroPAVER Software (from PAVER manual version 7.0)

Calculating PCI after Inspection

An Assessment Results window allows the user to view the condition of an individual section immediately after distress data is entered. To access this window, click Calculate Conditions in the Inspection Data Entry window. The section properties are displayed at the top of the window. In the middle of the window, Condition Index, Inspection Date, and Condition Value are displayed. This window also gives you basic information about the section that you are viewing:

Condition Indices: Displays the Condition Value for all conditions associated with the current section.

Sample Distresses: Displays a sections inspected sample units and their corresponding distress codes, descriptions, severity, quantity, density, and deduct.

Sample Conditions: The top displays a sections inspected sample units and the individual unit's sample type, size, and PCI. The bottom displays the number of samples surveyed and compares the total number of samples to the recommended number for a project level inspection.

Section Extrapolated Distresses: Shows each distress type from the Sample Distresses tab. Distresses are aggregated based on type and severity level. For random samples, distress quantities are adjusted to reflect the extrapolated value based on the sections total area. For any additional samples, distress quantities are extrapolated based on the additional samples true area. Extrapolated distress deducts are classified as resulting from load, climate, or other. The Distress Classification portion of the tab shows the percent of extrapolated distress deduct belonging to load, climate, and other.

Again, right-clicking any table provides Print and Export options. There is also a Print button at the bottom of the window.

EPCM Method

Evaluation of pavement condition is modeled by using visual basic language in software called the Evaluation of Pavement Condition Model (EPCM). The three main elements of the EPCM model: (1) networks definition, (2) evaluation of pavement condition and determination of the appropriate maintenance activity, and (3) prediction of pavement condition in future.

The procedure to find PCI can be summarized in the following steps 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). Determine distress value 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).

TABLE I. Table Type Styles

Severity level	F_S	Extent level	F_E
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	Very High Extent level	1

`TABLE II. Table Type Styles

Distress type	Weight value (W)
Alligator crack	10
Longitudinal crack	5
Slippage crack	5
Transverse crack	5
Shrinkage crack	5
Bleeding	10
Polished surface	10
Raveling	10
Patholes	10
Rutting	10
Corrugation	10
Depression	10

$DV = Fs \times F_E \times W$

Pavement condition index (PCI) is calculated by substracting sum of all distress values from 100.

$PCI = 100 - \Sigma DV$

Artificial Neural Network

Artificial neural networks (ANN), the most widely used pattern recognition and modeling systems, have been utilized to solve various problems in modern pavement engineering. There has been a wide variety of studies with the specific objective of applying ANNs in pavement engineering. However, the inherently nonlinear time series, such as that found in pavement condition deterioration process, are more suitable for analysis by the general nonlinear mapping provided by a neural network, than by linear based autoregressive models. Neural networks are nonlinear models that can be trained to map past and future data of a time-series, thereby uncovering the hidden relationships governing the data. A simple example of an artificial neural network is shown in figure 3.

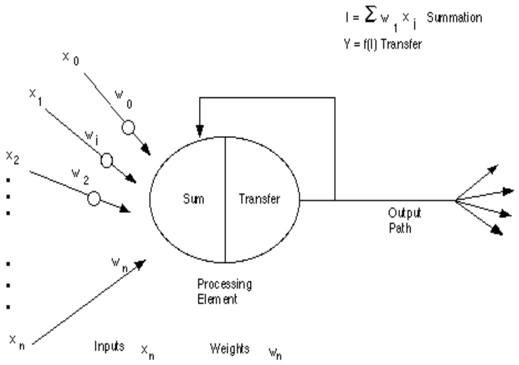

Fig.3. Example of an Artificial neural network

A neural network consists of a large number of simple processing elements called neurons, every neuron is connected by direct links, and each direct link has a weight associated with it.

ANN consists of a pool of simple processing units that communicate by sending signals to each other over a large number of weighted connections. Each unit performs a relatively basic task; receive input from neighbors or external sources and utilize that information to compute an output signal that is propagated to other units in the ANN. Next to the actual information processing task, weights have to be adjusted. An ANN is inherently parallel in the sense that many units can perform computation cycles simultaneously. ANN's distinguish among 3 types of units. (1) The Input Units that receive data from outside the net. (2) The Output Units that act as the ANN endpoints. (3) The Hidden Units where the input and output signals remain within the ANN framework

Activation Functions

An activation or transfer function acts as a transformation entity so that the output of a neuron in an ANN may be between certain values. Some of the more popular activation functions are: (1) The Threshold Function, (2) The Piecewise-Linear or Logistic Function, (3) The Sigmoid Function, An example of the sigmoid function would be the hyperbolic tangent function.

ANN – Training

An ANN has to be designed and implemented in a way that the set of input data results into a desired output (either direct or by using a relaxation process). Several methods to quantify the strengths of the connections can be applied. In other words, the weights can be set explicitly (utilizing a priori knowledge) or the net can be trained by feeding learning patterns into the solution and by letting the net change/adjust the weights according to some learning rule. Learning based solutions can be categorized as:supervised or associative learning, unsupervised learning, reinforcement learning.

Back Propagation

BP is simply the implementation of the gradient descend method to minimize the total squared error of the output computed by the network.

Genetic Programming

Genetic programming is a domain independent method that genetically breeds a population of computer programs to solve a problem. Specifically, genetic programming iteratively transforms a population of computer programs into a new generation of programs by applying analogs of naturally occurring genetic operations. The genetic operations include crossover (sexual recombination), mutation, reproduction, gene duplication, and gene deletion.

Preparatory steps of Genetic Programming

The set of terminals for each branch of the to-be-evolved program, the set of primitive functions for each branch of the to-be-evolved program, the fitness measure, certain parameters for controlling the run, he termination criterion and method for designating the result of the run.

III. Conclusions and Scope of the study

In this paper, an overview of different theoretical methods along with design has been summerised for the prediction of the pavement condition index. From this methods, we can calculates PCI for base year and future year based on visual surface condition survey.

The present overview can evaluates the present status of 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 proposed model can provide a reliable prediction of the PCI and can be used in the PMS.

The feasibility of the ANN and GP techniques in finding the solutions to nonlinear problems was summarized theoritically. Moreover, it is possible to improve the models with high precision of this study by retraining the models with practical cases when data are made available.

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