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An Overview Of Pavement Management System For Industrial Areas

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ABSTRACT

With the current surge in national economy the industrial traffic has increased many folds in terms of quantity of load and traffic volume. This results in early deterioration of the roads. Also the serviceability reduces hampering the industry's supply of raw material and transport of finished goods. An efficient road transportation system is of vitally important for smooth operations of industrial units. Construction of new roads needs an enormous investment. However, once constructed the road network system requires huge resources to maintain serviceability and to ensure safe passage at an appropriate speed and with low VOC (Vehicle Operating Cost). Road maintenance is therefore an essential function and should be carried out on a timely basis. The cost of providing and maintaining the roads for the industrial areas at an acceptable serviceability level is quite high. It is therefore essential for a transportation engineer to attempt establishing an acceptable pavement condition level from economic, safety and environmental point of view. In today's economic environment of constrained budgets, as the existing road infrastructure has aged, a more systematic approach towards determining maintenance and rehabilitation needs is necessary. The efficient pavement management system shall provide objective information and useful analysis to ensure consistent and cost effective decisions related to preservation of existing industrial road network in healthy condition.

Keywords- Pavement, maintenance, management rehabilitation, transportation

I INTRODUCTION

An efficient road transport system is seen by most countries as an essential pre-condition for economic development, and considerable resources are devoted to road construction and improvements. The resultant road network usually have an asset value that represents a significant proportion of national wealth, and the road sub-sector should make an important contribution to gross national product (GNP). It is therefore, an important and appropriate that this asset is managed in a businesslike manner, and the attention of an increasing number of road professionals is now being directed to this activity.

Compared with construction, the problem of managing road maintenance has proved to be a particularly difficult issue for many countries [World Bank, 1988]. Road network are, by their nature, spread over a wide geographic area, and their condition is changing continuously because of the effects of traffic, climate and environmental conditions. The effect on this of maintenance interventions is complex, and is often difficult to predict, particularly over the longer term.

Large road networks built at great expense have been under-maintained and more heavily used than expected. If this neglect continues, the deterioration of roads will accelerate as old pavements crumble and new ones outlive the initial period during which the effects of neglect are barely perceptible [World Bank, 1988].

The definition of maintenance varies among the agencies. In a physical sense, maintenance consists of a set of activities directed towards keeping a structure in a serviceable state. For pavements, this includes such work as patching, crack filling, and so on [Hass, 1978].

Mohammed Taleb Obaidat & Sharaf A. Al-kheder in 2006 reported a work combining GIS and PMS. The objective of their research work was to investigate the potential of integration of geographic information system (GIS), global positioning system (GPS) and computer vision system (CVS) for the purpose of flexible pavement distresses classifications and maintenance priorities. The classification process included distress type, distress severity level and options for repair. A system scheme that integrated the above-mentioned systems was developed. The system utilized the data collected by GPS and a PC-based vision system in a GIS environment. GIS Arc view software was used for the purpose of data display, query, manipulation and analysis. Their work was one of the most guiding works for developing countries. The statistical models developed were found quite useful for the researchers in developing world as well.

The Pavement Management System (PMS) is a set of tools or methods that assist decision-makers in finding optimum strategies for providing, evaluating, and maintaining pavements in a serviceable condition over a period of time.[AASHTO Guide for Design of Pavement Structures (1993)]

The concept of PMS was realized in India only in the mid eighties. Since then, a number of important studies of direct or indirect interest to pavement management system have been planned and conducted. The issue and need of maintenance management of pavements have received considerable attention during the recent past. Of late, PMS in India has got some impetus and efforts are now on to develop computerized pavement management systems for various categories of roads. The extensive studies have been carried out on efficient pavement management system by CRRI (Central Road Research Institute), IIT Roorkee and in various state government agencies like PWD etc. If we compare with construction management the road maintenance proved more difficult. The maintenance should be with respect to traffic, climatic conditions, environmental conditions etc. For development of PMS, HDM-4 (Highway Development and Management System) software plays important role as it is a universal tool for deciding the development and maintenance strategy for road network.

The various parameters are involved in PMS which includes soil conditions, terrain type, and traffic volume pavement conditional characteristics of road network. GIS (Geographic Information System) shall also help in development of PMS which gives graphical output analysis. It also reporting about the network level PMS.

Pavement rehabilitation and repair methods selection is one of the key issues. In order for Pavement Management Systems (PMS) to be effective, they must be based on a reliable, statistically sound means for the rehabilitation and repair methods that are present on the system. To make sensible life cycle cost decisions in design and rehabilitation, pavement engineers must be able to account for distress phenomena and repair methods.

Road networks are one of the most important economic activities in modern industrialized societies that constitute an enormous investment of public funds. In order to protect this investment, large sum of money are required to sustain and maintain the networks in an adequate condition. The management of these networks is the difficult task for transportation agencies. The task is becoming more complicated by the limited of funds combined with the continuously deterioration of pavement structures over time due to environmental factors and increasing traffic loads. This scenario has forced the agencies to look for better procedures or strategies for maintenance and rehabilitation of the existing pavements.

Over a steadily research into pavement management methods has brought the development of pavement management systems (PMS). These systems are designed to provide a structured and comprehensive approach to pavement management. They assist decision makers in finding strategies for providing and maintaining pavements in a serviceable and safe condition at the most possible cost effective way. The primary functions of PMS are to improve the efficiency of decision making, expands its scope, provide feedback on consequences of decisions, and insure the consistency of decisions made at different levels within the same organization.

PMS provides consistent, objective and systematic procedure for determine priorities, schedule, allocating resources, and budgeting for pavement maintenance and rehabilitation. The goal of most PMS is to maximize the effectiveness of pavement maintenance and rehabilitation by using maximum benefits of the available fund. In general, the process of PMS consists of four main components: Network inventory, pavement condition evaluation, performance prediction models, and planning method (Shahin 1994).

Mathematical failure theory has been effectively used by researchers to finalize the rehabilitation strategy for pavement. The methodology presented in the paper gives the engineer the ability to statistically and probability consider different rehabilitation and repair method and statistically and probability factors in computing the life cycle costs for rehabilitation and repair methods selection [Fereidoon Moghadas Nejad1, Et al, 2009]

Previously the roads in the Industrial Area were merely designed with respect to the vehicular traffic at that time i.e., in the decade of 70's, 80's. Further no updates in the standards of roads, cross-section of roads with respect to the traffic of new generation's vehicles were made. In order to incorporate the new generation vehicles in terms of operating characteristics and design of road with respect to the investment strategy in road project considering present and future conditions is the need of maintenance authority. The basic concept is to provide efficient road transport system for economical industrial development.

II OBJECTIVE

The objective of the study is to develop a Pavement Management System (PMS) for identified industrial areas in Vidarbha to assist the engineers responsible for maintaining the roads, as well as the authorities responsible for allocating funds, in making consistent and cost effective decisions, related to maintenance and rehabilitation of pavements.

This requires development of a systematic procedure that would predict the most economical maintenance strategy for a particular pavement section at project level, and optimization &

prioritization of such maintenance activities in case of constrained budget, at the network level.

The study would take into account different type of pavement sections, pavement composition, traffic conditions, terrain and climatic conditions in the above road network. Flexible pavement has been taken into consideration in this study.

III SCOPE

The scope of study encompasses the following:

a) Development of a methodology for Pavement Management System for the identified areas in Vidarbha.

b) Study and use of various parameters of World Bank's highway project appraisal model HDM-4, which are relevant to the Indian geographical and climatic conditions and can be applied to areas under study.

c) Development of a time series database consisting of inventory data, pavement condition data, traffic data, and other necessary data, for the selected areas, to provide necessary inputs for executing the HDM-4 model.

d) Collection of road user cost data and costs of different types of maintenance activities, from field and the relevant Government publications.

e)Calibration of the pavement deterioration models incorporated in HDM-4, on the basis of the Pavement Performance Study carried out in India.

f) Validation of the calibrated pavement deterioration models using the data collected from the identified areas.

g) Application of the developed Pavement Management System methodology at the Project Level for the maintenance management of individual pavement sections.

h) Application of the developed Pavement Management System methodology at the Network Level for optimization and prioritization of the maintenance management strategies for the whole network.

i) Integration of PMS with Geographical Information System using the GIS software and presentation of results in graphical formats for easy understanding and quick decision-making.

IV METHODOLOGY

a)Identification of Network
b)Data Collection
c)Data analysis and database building
d)Detailed micro-level study for identifying the causative factors for road deterioration.
e)Suggesting resource based method for maintenance of the roads

a.***Identification of Network:*** The network of roads at various Industrial Areas are identified viz. Butibori, Hingna, Amravati, Chandrapur, Umrer etc. at Vidarbha region in Maharashtra state, India. The total length of road is 345 km which is considered in this study.

b.***Data Collection:*** The data collection is in progress which includes :

- Inventory data
- Name and category of road ,Carriageway width, Shoulder width, Drainage conditions, Surface type and thickness ,Pavement layer details
- Structural evaluation (structural capacity)
- Functional evaluation (pavement condition and riding quality)
- Surface Distress Measurements
- Cracking area , Ravelling area , Pothole area , Rut depth measurements , Edge break area measurements , Surface deterioration area measurements ,
- Evaluation of pavement material
- Field evaluation
- Thickness of the most recent surfacing course and old surfacing courses, Thickness of base and sub-base courses, Field density and field moisture content of the soil sub grade
- Laboratory Evaluation
- Atterberg's limits (Liquid limit and Plastic limit), Proctor density and optimum moisture content ,CBR (un-soaked and soaked at field conditions),Field moisture content

c) Data analysis and database building: Data analysis is started with building of some mathematical models. The applicability of these models is under testing. Some of the models are discussed as follows:

Pavement Condition Indicator: Whatever strategy is adopted for pavement management, it becomes important to assess the pavement's structural and functional qualities in a scientific, well-defined way. There are generally two philosophies of achieving that goal. One way is to combine attributes in a specific manner to determine a single pavement condition index universal to each section. By doing so, it is important to note that the index be objective and reflective of the real-world pavement status since the ultimate effectiveness of the decision is based upon the validity of this single index.

Equally important, data should be updated on a periodical basis in order to be reflected in the index. The other philosophy is to use more than one condition indicator in decision trees, to prioritize and coordinate between difference indices and condition states, or to tabulate a pavement condition matrix. In this case there are usually several indices related to the extent of various types of surface distress.

While some agencies use multiple indexes to establish priorities between several pavements in need of repair, aggregation of pavement condition data into a single rating number is widely used to support project and network level decisions in pavement management. To

characterize each pavement condition attribute and its time-decay relationship with traffic, age, climate, and other variables, various models have been developed.

Performance Modeling: Performance modeling refers to the activity that patterns and predicts the deterioration of pavement conditions with accumulating use, based on comprehensive evaluation of the structural and functional characteristics of the pavement in service, deterministically and/or empirically. A typical performance curve, relating the pavement condition rating to the age of the pavement, is shown as an example in figure 1.

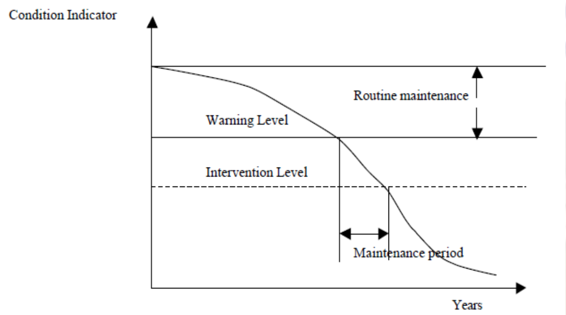

Figure 1

Being able to predict the condition of pavements is the most essential activity to the management of pavements at the network and the project levels, both technically and economically. In fact, the models play a crucial role in several aspects of the PMS, including financial planning and budgeting as well as pavement design and life cycle economic analysis.

First, models are used to predict when maintenance should be required for individual road sections and how to prioritize competing maintenance alternatives. Second, by virtue of its prediction capability, the model enables the agency to estimate long-range funding requirements for pavement preservation and to analyze the consequences of different budgets on the condition of the pavement network.

Third, because the models attempt to relate the influence of predicting variables to pavement distresses or to a combined performance index, they can be used for design as well as the life-cycle economic evaluation. Pavements are complex physical structures responding in a complex way to the influences of numerous environmental and load-related variables and their interactions.

A prediction model, therefore, should consider the evolution of various distresses and how they may be affected by both routine and planned maintenance. Such an approach is so highly complex that a compromise procedure combining a strong empirical base and a mechanistic approach is adopted to achieve a reliable model. The empirical base includes time-series pavement condition data compiled on pavements exposed to different environmental and loading conditions.

With regard to mechanistic principles, interactions between traffic loading and pavement strength parameters, between loading and pavement deflections, and so on, are observed and included when significant. These considerations dictate the model form and provide guidance in the selection of the independent variables for inclusion in the prediction model. **Pavement Performance Prediction Methodologies**: Performance is the “ability of a pavement to fulfill its purpose over time”. A performance prediction method is “a mathematical description of the expected values that a pavement attributes will take during a specified analysis period” (AASHTO guidelines).

Prediction models provide parameters to pavement management optimization so that they can base the selection of future M & R programs on the forecasted conditions.

Performance curves: A performance curve defines variations of pavement attributes over time for their particular conditions. A bituminous pavement with high traffic and low subgrade strength may have a different performance curve than a concrete pavement with low traffic and medium subgrade strength. A performance curve normally relates expected relationships between serviceability and age. These relationships are commonly estimated using regression, include structural capacity versus age, skid resistance versus age, and a measure of distress versus age.

Nondestructive testing (NDT): O’Brien, Kohn and Shahin studied Prediction of pavement performance using NDT results. The NDT model was originally used by several states. Several variables were included in this model: pavement type, condition rating, NDT information, pavement construction, traffic information, and pavement layer thickness. The independent variables were pavement construction history, a weighted traffic variable, and NDT deflection parameters. The pavement construction history was reflected in three pavement layer age variables: time since last overlay, time from construction to first overlay, and total pavement age. The NDT parameters were a normalized deflection factor given by the slope of the deflection basin and a measure of the deflection basin area. The traffic variable included in the prediction model is the natural logarithm of current traffic count weighted by traffic type. The relevant significance of each variable group was 60 percent for the age variables, 30 percent for the NDT variables, and 10 percent for the traffic variable.

Regression Analysis: Regression Analysis is the approach that is most commonly used. A General Linear Model or polynomial model procedure is often used to develop a linear regression equation. In most regression analyses, the fit of the model is described by an R-square (R^2) value. The R^2 value is based on sample correlation coefficients that indicate the strength of the developed relationship between the dependent variable and independent variables when compared to the observed data. R^2 may then be interpreted as the proportion of total variability in the dependent variable that can be explained by the independent variables. The R^2 can range from zero to one with the higher number indicating a better fit of the model to the actual data.

Empirical-Mechanistic Model: This model is based on the assumption that a prediction model should consider the evolution of various distresses and how they may be affected by both routine and planned maintenance. However, this approach is so complex that a compromise procedure combining a strong empirical base and a mechanistic approach is adopted to achieve a reliable model. The empirical base includes time-series pavement condition data compiled on pavements exposed to different environmental and loading conditions. With regard to mechanistic principles, interactions between loading and pavement deflections, and so on, are carefully observed and included when significant. The dependent variable is usually condition data (e.g. PCR, stands for Pavement Condition Rating). The selection of independent variables is based on experience suggesting that the prediction of pavement condition depends on:

(1) period during which the pavement has been in service, age of the pavement;

(2) traffic volume and weight, which are expressed in

terms of years equivalent single-axle loads (ESALs);

(3) thickness of last overlay in inches;

(4) strength and condition of pavement structure represented by modified structural number.

Markov chain: The Markov chain is a probabilistic model that accounts for the uncertainties present with respect to both the existing pavement condition and future pavement deterioration. The underlying concept of this method is that a pavement section may be in one of several states or conditions and that unless maintenance or rehabilitation is undertaken, the condition of the pavement will worsen over time. The amount of pavement deterioration in a given period, such as a year, is a random variable depending only on the most recent state of the pavement and the amount and type of traffic loading that the pavement accrues during that period of time.

Optimization: When evaluating pavement conditions to decide on appropriate actions, it is necessary to define a set of intervention levels in accordance with the various types of data collected. Intervention levels could be defined based on a particular rating of pavement conditions to indicate the need for rehabilitation or preventive maintenance. Many different solutions are possible when the need for maintenance work arises, and each solution generates its own performance curve (according to the different criteria). Not only are many solutions possible, but also a tremendous number of different combinations are possible, when the timing, sequence or type of action are changed over an extended period (OECD, 1987). Figure no 2, illustrates an example with two different maintenance strategies. In the first case the maintenance work was made at a certain warning level, while in the second case the work was not carried out until the intervention level was reached. The cost of the maintenance work at time t2 may be greater than if the work had taken place at t1, or in other words, the actual cost of strategy two is higher than the first strategy. Potentially if the period of deferral lengthens, it causes much larger and non-economic expenditures when the remedial maintenance work is ultimately carried out.

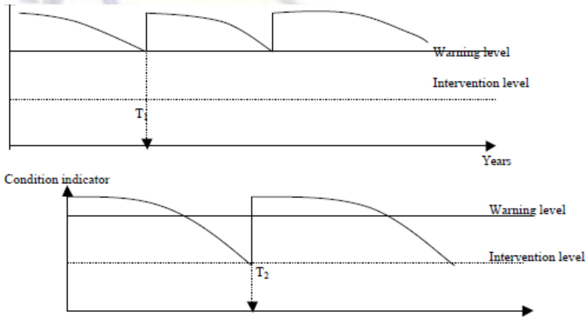

Figure 2

By analyzing costs and benefits of all possible strategies for each road section within a set time frame, called the consideration period, the consequences of providing satisfactory pavement service can be estimated. Computer programs are available to assist with the complexity that arises when addressing thousands of roads at various stages in their life cycle.

V CONCLUSION

The study shall end up in a model that will be useful for planning pavement construction and maintenance strategy in scientific manner ensuring rational utilization of limited maintenance funds. It shall help for better support from decision makers and serve as a window in developing and maintaining road network economically and efficiently.

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