USE OF MICROPAVER™ FOR BUDGET AND PROJECT PLANNING

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ABSTRACT

MicroPAVER™ is a Pavement Management System developed by the US Army Corps of Engineers through funding from the U.S. Air Force, U.S. Army, U.S. Navy, Federal Aviation Administration, and Federal Highway Administration. The Pavement Condition Index (PCI), part of MicroPAVER™, has been adopted by NATO and as standard practice by ASTM (ASTM D5340 for airfields and D6433-03 for roads).

The primary objective of this paper is to present the latest engineering technology in MicroPAVER™ for pavement maintenance and rehabilitation (M&R) planning. Specifically, M&R budget scenario analysis and M&R project planning and formulation. The paper will include a discussion of the following topics:

1. The use of "family modeling" for prediction pavement condition.
2. Crediting increased pavement performance when including preventive M&R as part of work planning.
3. Performing budget scenario analysis for different management objectives such as reaching a stated condition or eliminating M&R backlog in a specified number of years.
4. Use of the results of M&R budget optimization at the pavement section level as a guide to formulating projects that may consist of different work types and span multiple pavement sections.

1 INTRODUCTION

In the past, pavements were maintained, but not managed. The pavement engineers experience tended to dictate the selection of Maintenance and Repair (M&R) techniques with little regard given neither to life cycle costing nor to priority as compared to other pavement requirements in the network. In today's economic environment, as the pavement infrastructure has aged, a more systematic approach to determining M&R needs and priorities is necessary. Pavement networks must now be managed, not simply maintained.

A Pavement Management System (PMS) provides a systematic, consistent method for selecting M&R needs and determining priorities and the optimal time of repair by predicting future pavement condition. The consequences of poor maintenance timing are illustrated in Figure 1. If M&R is performed during the early stages of deterioration, before the sharp decline in pavement condition, over 50% of repair costs can be avoided. In addition to cost avoidance, long periods of closure to traffic and detours can also be avoided. A PMS is a valuable tool that alerts the pavement manager to the critical point in a pavement's life cycle.

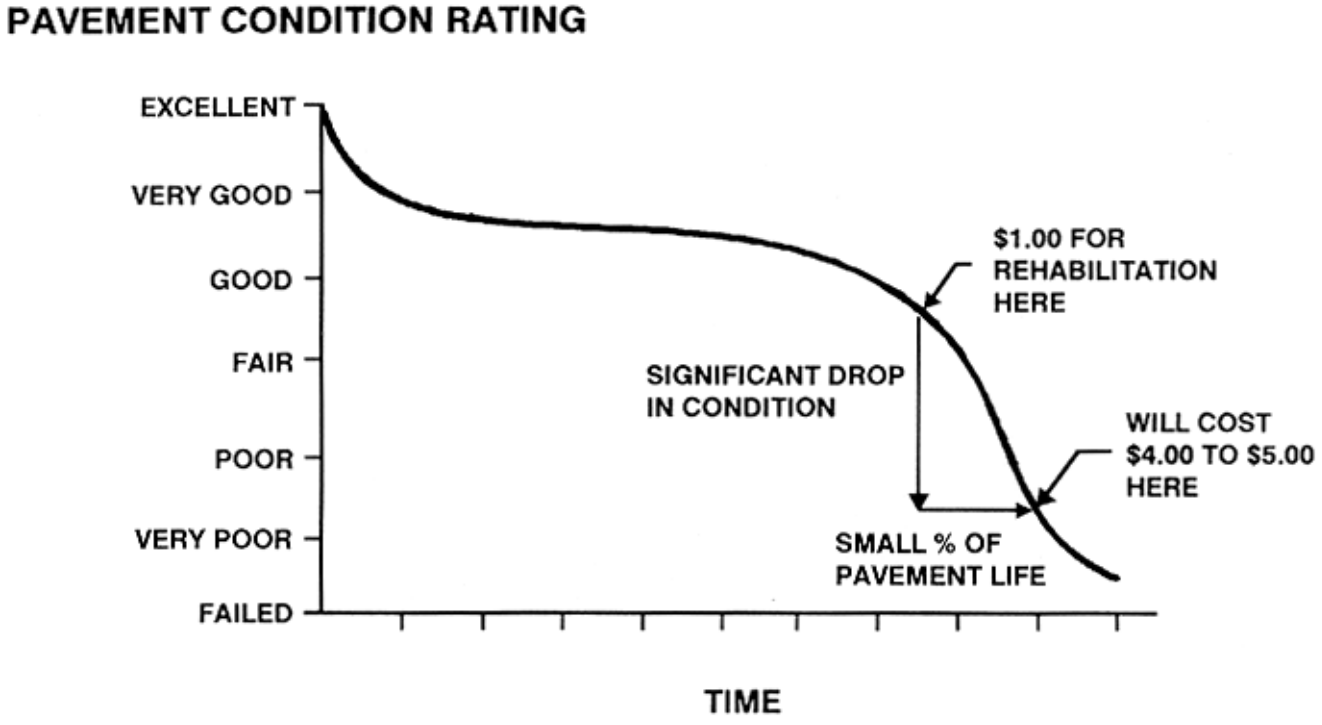

Figure 1

2 PAVEMENT MANAGEMENT PROCESS

The ad hoc approach to pavement management normally leads to gradual deterioration in the overall condition of the pavement network and thus increased backlog of unfunded major M&R requirements. This approach consists of the habitual application of selected few M&R alternatives (such as 1.5 inch overlay) to pavement that are either in very poor condition or politically important. This is normally done regardless of the needs of the other pavements in the network.

A systematic approach to pavement management is needed to insure optimum return on investment. The following approach has evolved over the past thirty years as part of the development of the PAVER pavement management system, and consists of the following steps:

1. Inventory
2. Inspection
3. Condition Prediction
4. Condition Analysis
5. Work Planning
6. Project Formulation

MicroPAVER™ provides pavement management capabilities to: (1) develop and organize the pavement inventory; (2) assess the current condition of pavements; (3) develop models to predict future conditions; (4) report on past and future pavement performance; (5) develop scenarios for M&R based on budget or condition requirements; and (6) plan projects.

2.1 Inventory

MicroPAVER™ inventory management is based on a hierarchical structure composed of networks, branches, and sections, which allows users to easily organize their inventory while providing numerous fields and levels for storing pavement data.

The first step in establishing a PMS is the network identification. A network is a logical grouping of pavements for M&R management. The grouping may be based on facility types being managed, funding sources, minimum operational standards, or geographical location. An airport may identify its pavements as two networks, one for airfields and one for roads and parking lots.

A branch is a readily identifiable part of the pavement network and has a distinct use. For example, an airfield pavement such as a runway or a taxiway would each be considered a separate branch.

A branch does not always have consistent characteristics throughout its entire area or length, so for managerial purposes a branch is divided into smaller components called sections. A section should be viewed as the smallest management unit when considering the application and selection of major M&R treatments. When dividing branches into sections, consider pavement structure, construction history, traffic, pavement rank and functional classification, drainage facilities and shoulders, condition, and size. One of the most important criteria for dividing a branch into a section is pavement structure. The structural composition (thickness and materials) should be consistent throughout the entire section. Construction records serve as a good source of this information, and can be verified by taking a limited number of cores.

Section size can have a considerable impact on the economics of implementation. Defining very short sections, to ensure uniformity, requires a higher implementation effort and cost. If they are too large, the characteristics may not be consistent across the entire area, causing non-uniform sections that result in inefficient design and budget decisions.

Figure 2 is an example of a civil aviation airfield pavement network being divided into branches and sections. The network is divided into three branches: Runway 8-26, Taxiway, and Apron. The runway is 5,000 feet long, and is divided into two sections, A and B, based on construction history, condition, and traffic. The runway keel is not identified as a separate section due to the width of the runway, which is only 100 feet.

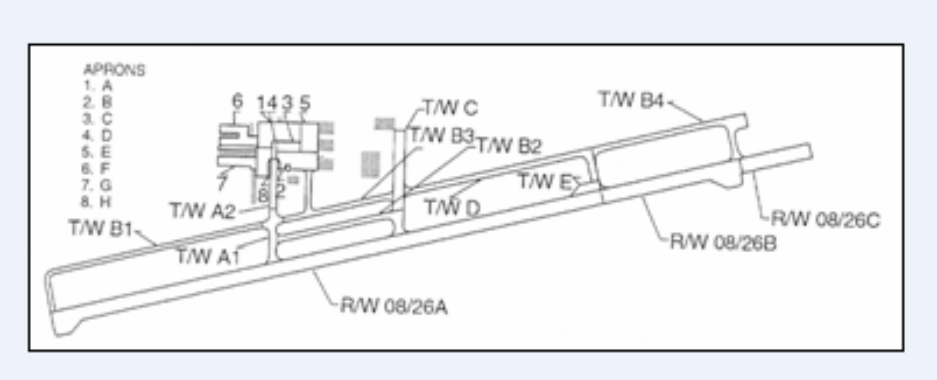

Figure 2

2.2 Inspection

To assess pavement condition, MicroPAVER™ uses the Pavement Condition Index (PCI) as its primary standard. Calculation of the PCI is based on the results of a visual condition survey in which distress type, severity, and quantity are identified (Figure 3). The PCI measures pavement structural integrity (not capacity) and surface operational condition, on a scale from 0 to 100. PCI ratings correlate with the needed level of M&R, and agree closely with the collective judgment of experience pavement engineers. ASTM has adopted the PCI as standard practice for roads (D-6433-03) and airfields (D-5340-04). MicroPAVER™ provides users the ability to customize the PCI condition rating categories, as well as a user interface for recording the results of an inspection and an online distress user guide. The distress information obtained as part of the PCI condition survey provides insight into the causes of distress, and whether it is related to load or climate.

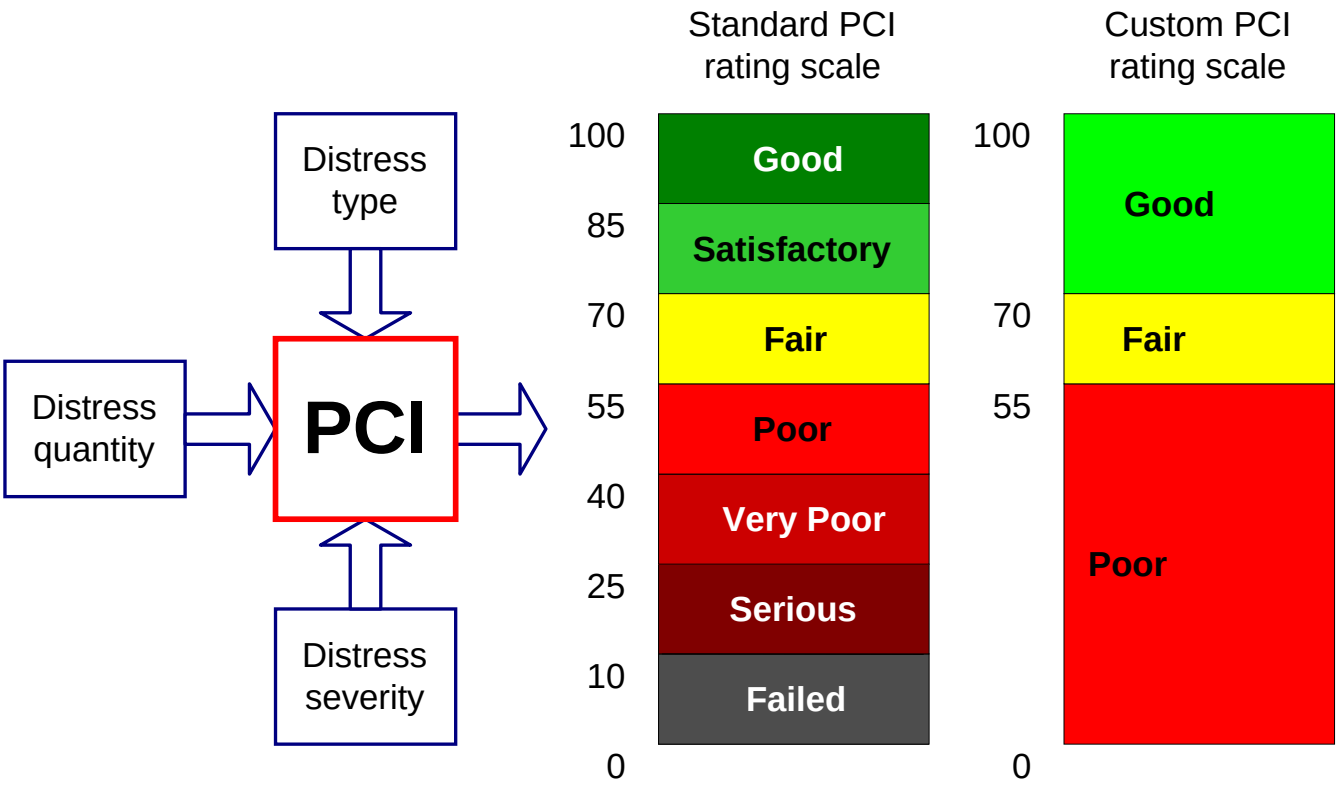

Figure 3

The PCI calculation procedure can be used to calculate other specialty distress indices using specific distress types and severities. For example, one can decide to calculate a structural index based on structurally caused distresses only such as alligator cracking, rutting, and potholes. Using this procedure, a Foreign Object Damage (FOD) Potential was developed as part of MicroPAVER™. The FOD index correlates with the potential danger to aircraft engines by foreign objects generated by pavement distresses.

2.3 Condition Prediction Modeling

The Prediction Modeling function in MicroPAVER™ helps identify and group pavements of similar construction that are subjected to similar traffic, weather, and other factors which affect pavement performance. This is important, as no one prediction model will work for all locations and conditions. Pavement condition historical data are used to build a model that can more accurately predict the future performance of a group of pavements with similar attributes, which is important for the analysis of different budget consequences. Condition prediction models are used at both the network and project levels to analyze the condition and determine maintenance and rehabilitation (M&R) requirements.

Following is a description of the PCI Condition Prediction techniques used in MicroPAVER™.

2.3.1 Straight-Line Extrapolation as a Technique for Developing Prediction Models

The simplest condition prediction is based on straight-line extrapolation of the last two condition points. This method is applicable only for individual pavement sections and does not lead to the development of a model that can be used with other pavement sections. The method assumes that traffic loading and previous maintenance levels will continue as in the past. This method requires that at least one condition measurement has been performed since construction, thereby providing two points: an initial pavement condition that can be assumed at the time of last construction, and a second pavement condition determined at inspection time. The straight-line extrapolation is used because the pavement family trend is not known and therefore it is not known if the rate of deterioration is likely to increase or decrease (Figure 4).

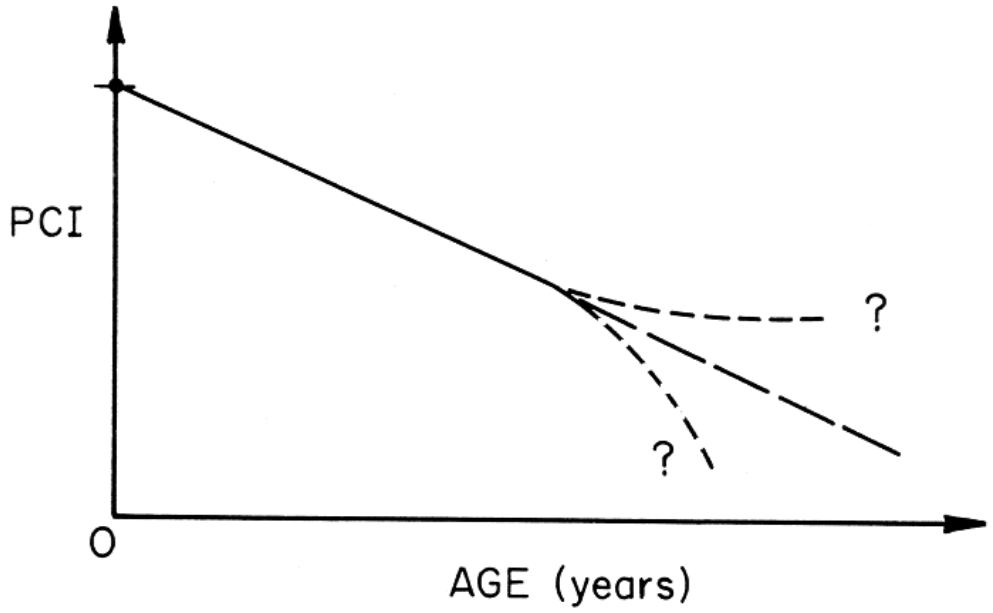

Figure 4

It should be noted that when predicting the condition of an individual pavement section, factors such as foundation support, climate, pavement structure, and the past traffic are all accounted for. Although this method of predicting deterioration is accurate enough for a short period of time (a few years), it is not accurate for long periods of time. Also, the straight-line extrapolation method cannot be used to predict the rate of deterioration of a relatively new pavement or a pavement that has recently received major rehabilitation.

2.3.2 Family Condition Deterioration Model

An extensive research program, conducted as part of the PAVER research, resulted in the development of the Family Method, which consists of the following steps:

1. Define the pavement family
2. Filter the data
3. Conduct data outlier analysis
4. Develop the family model
5. Predict the pavement section condition

The method was designed for use with MicroPAVER™ to predict PCI vs. time. However, the concept can be extended to predict other condition measures. A description of the above steps as used in MicroPAVER™ follows.

2.3.2.1 Define the Pavement Family

A pavement family is defined as a group of pavement sections with similar deterioration characteristics. The MicroPAVER™ system allows the user to define a family based on several factors including use, rank, surface type, zone, section category, last construction date, and PCI. Figure 5 is an example family definition using three of the factors: use, type, and rank. The user may define as many families as required for accurate condition

prediction. Data availability may impose a limitation on appropriate family definition. For each defined family, a data file is automatically created by MicroPAVER™ containing pavement section identification, age, and PCI.

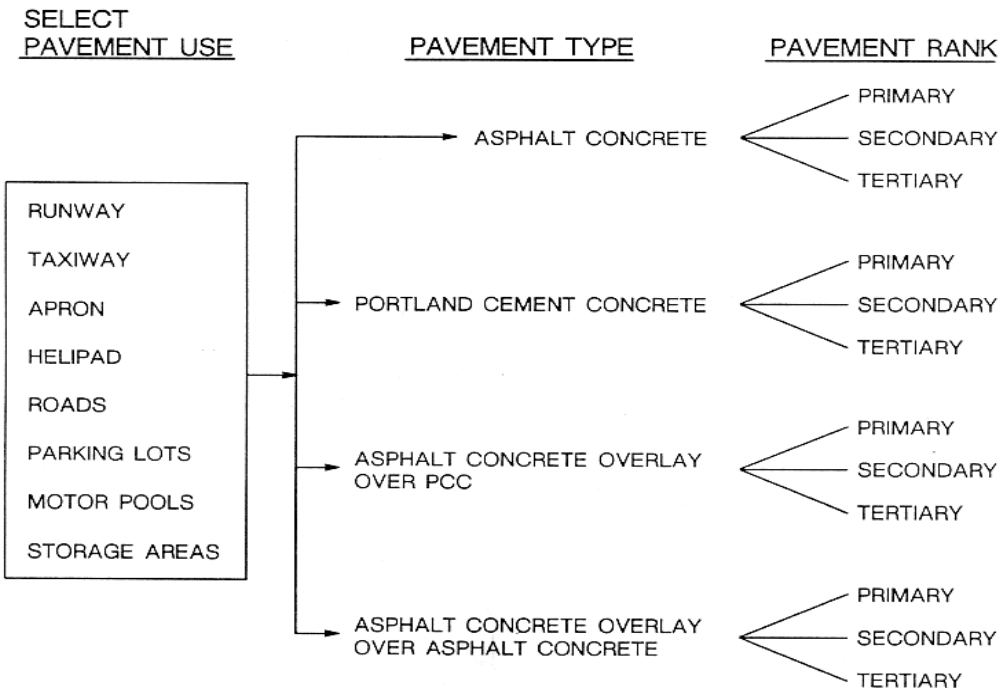

Figure 5

2.3.2.2 Filter the Data

In this step, MicroPAVER™ allows the user to filter out suspicious data points through establishing a set of boundaries defined by a maximum and minimum envelope expected over the life of the pavements. The program includes a default envelope developed by reviewing many databases; however, the user can easily modify these values. If a record falls outside the envelope boundaries, the record is moved to the 'errors' file.

2.3.2.3 Conduct Data Outlier Analysis

The data-filtering procedure is used to remove obvious errors in the data as described above. Further examination of the data for statistical removal of extreme points is performed in the outlier analysis. This step is important because pavements with unusual performance can have a substantial impact on the way family behavior is modeled.

MicroPAVER™ calculates the prediction residuals, which are the differences between the observed and predicted PCI values, using a polynomial least-error curve. The residuals were found to have a normal frequency distribution, which allowed a confidence interval to be set. For example, an interval of three standard deviations in both directions contains 99.8% of the observed PCIs. MicroPAVER™ allows the user to specify the confidence interval. Sections that are detected as outlier based on the confidence intervals are identified (Figure 6) and removed to the outlier error file.

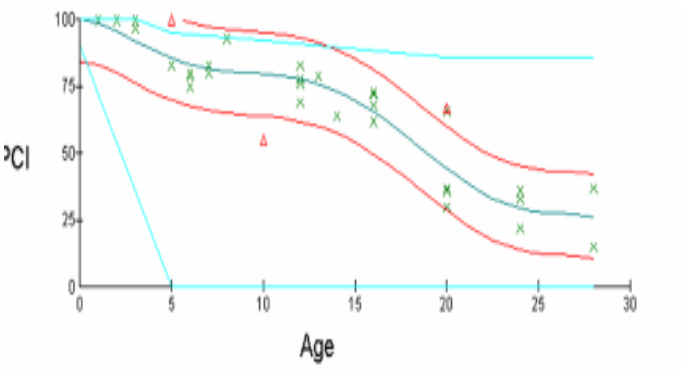

Figure 6

2.3.2.4 Develop the Family Model

A polynomial constrained least squared error is developed using data after being processes through the filtering and outlier analysis. The degree of the polynomial is determined to minimize the standard estimate of error of the residuals. This polynomial is constrained in that it is not allowed to have a positive slope because the PCI cannot increase with age. At the request of the user, an unconstrained best fit can be viewed if a positive PCI vs. age slope is detected. This is a useful feature because it may imply a heterogeneous family. It also helps the user view where the problem is occurring.

This best-fit curve for the family analysis extends only as far as the available data. To predict future conditions, the curve is extrapolated by extending a tangent of the same slope as that of the curve at the last few years (currently set to 3 years).

2.3.2.5 Predict the Pavement Section Condition

PCI prediction at the section level uses the curve from the pavement family prediction model. The prediction function for a pavement family represents the average behavior (trend) of all the sections of that family. The prediction for each section is done by defining its position relative to the family prediction curve. It is assumed that the deterioration of all pavement sections in a family is similar and is a function of only their present condition, regardless of age. A section prediction curve is drawn through the latest PCI/ age point for the pavement section being investigated, parallel to the family prediction curve as shown in Figure 7. The prediction PCI can then be determined at the desired future age.

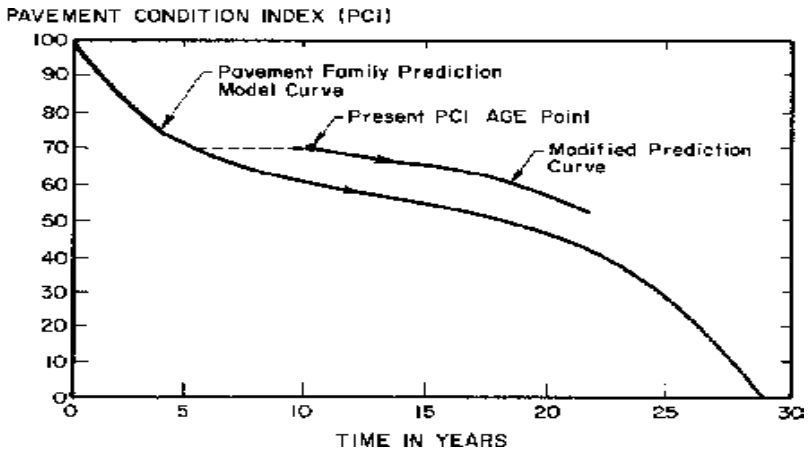

Figure 7

Comparing the section to the family deterioration provides invaluable feedback on the effect of maintenance, traffic, drainage, and other factors on pavement behavior. This type of feedback is invaluable as a guide for revising pavement thickness design procedures. The family method was developed so that when more data are incorporated into the database, the deterioration model is continuously updated.

2.4 CONDITION ANALYSIS

The Condition Analysis feature allows users to view the past, current and future conditions of the entire pavement network or any specified subset of the network, assuming no major M&R is performed. Past conditions are reported based on prior interpolated values between previous inspections, and future conditions are based on prediction models. Condition analysis provides managers with the ability to assess the consequence of past budget decisions and the value of having a management system, especially if the system has been in place for several years. In MicroPAVER™, conditions can be viewed on GIS maps in addition to tables and graphs (Figures 8 and 9).

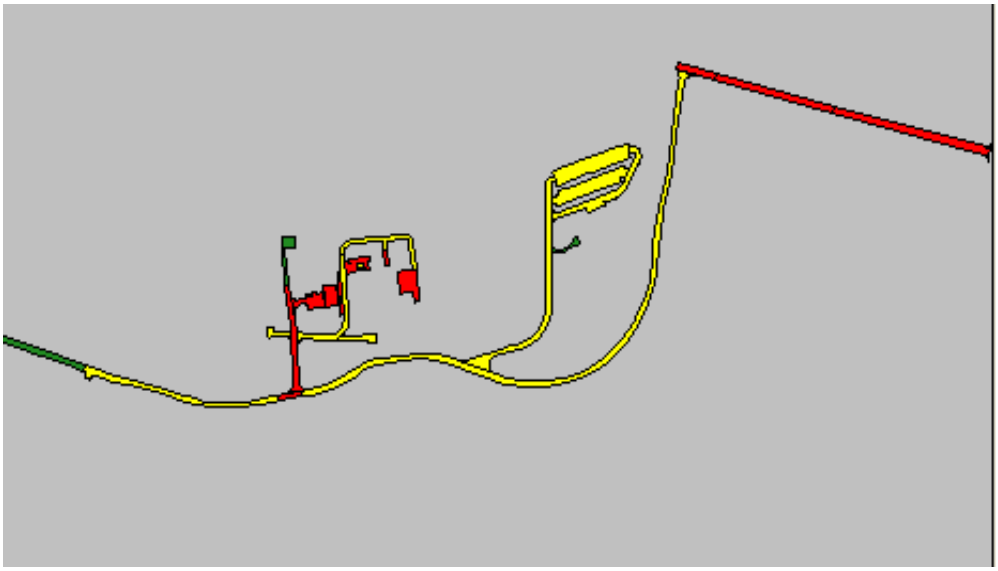

Figure 8

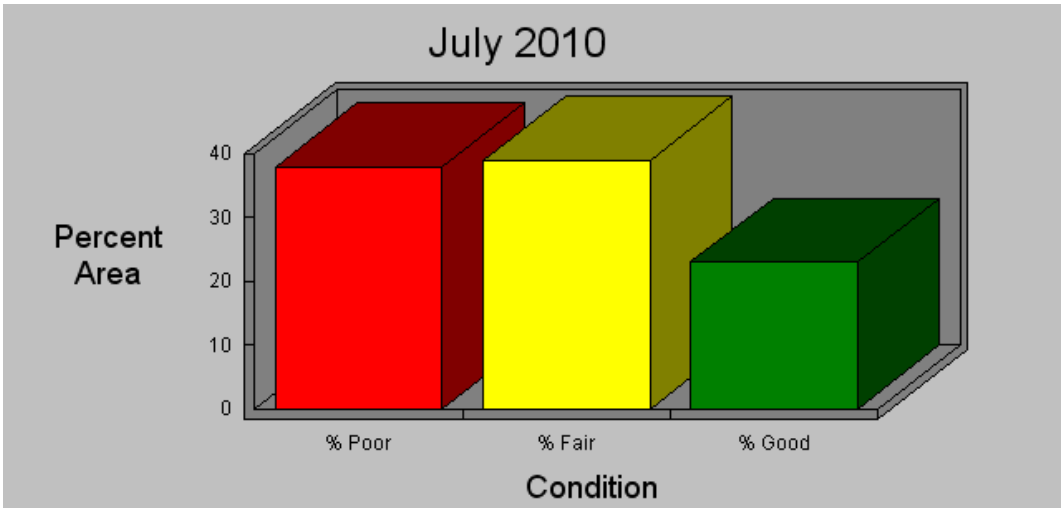

Figure 9

The main purpose of pavement condition analysis is to determine changes in pavement condition. Primarily, how is the pavement condition now compared to the condition x years in the past and what would it be y years in the future if no preventive or major M&R is performed? Past pavement condition (prior to last inspection date) is determined by interpolation using last construction date (last major M&R date) and previous inspections. Future pavement condition (after last inspection date) is determined using condition prediction techniques. In MicroPAVER™ this is performed using the pavement's assigned condition deterioration family. Condition Analysis is very beneficial to pavement managers since it provides feedback on pavement condition performance (condition over time) as a result of previous M&R budget spending and management policies. Also, being able to compare the condition of pavement sections at a selected date is an important feature since the pavement sections may have been inspected at different times.

2.5 WORK PLANNING

The MicroPAVER™ Work Planner is a tool for planning, scheduling, budgeting, and analyzing alternative pavement maintenance and repair (M&R) activities. Work Planning provides the ability to determine budget consequences for a specified budget or, alternatively, budget requirements to meet specified management objectives. Typical management objectives include maintaining current network condition, reaching a certain condition in x years, or eliminating all backlog of major M&R in x years. Regardless of the analysis scenario, the output should include the recommended M&R category for each pavement section for each year of the analysis. Projects are formulated by grouping sections to minimize cost and traffic delays.

Maintenance and rehabilitation is also called maintenance and repair by some agencies. Therefore the 'R' in 'M&R' can be interpreted as either rehabilitation or repair. M&R methods fall under three categories: localized, global, and major. Localized M&R can be applied either as a safety (stop-gap) measure or preventive measure, and includes patching and

crack sealing. Global M&R, surface treatments for asphalt surfaced pavements, is cost effective when applied as a preventive measure. Major M&R is used to correct or improve structural and functional requirements. Major M&R is often economically justified for deteriorated pavements, pavements deteriorating at a rapid rate, and pavements subjected to a change in traffic loading.

When performing work planning in MicroPAVER™, sections are assigned to M&R Families to establish groups of pavements which would use different pavement cost tables, or receive similar types of M&R work. The Work Planner uses the M&R Families along with inspection data, maintenance policies, maintenance costs, and predictions of future pavement conditions to recommend M&R categories (localized, global, or major), at the section level for each year of the analysis period.

MicroPAVER™ provides the ability to determine the consequence of a selected budget on pavement condition and the resulting backlog of Major M&R (unfunded major M&R). The MicroPAVER™ work plan is also used to determine budget requirements to meet specific management objectives. This enables managers to develop a variety of funding scenarios to support their decisions (Figure 10).

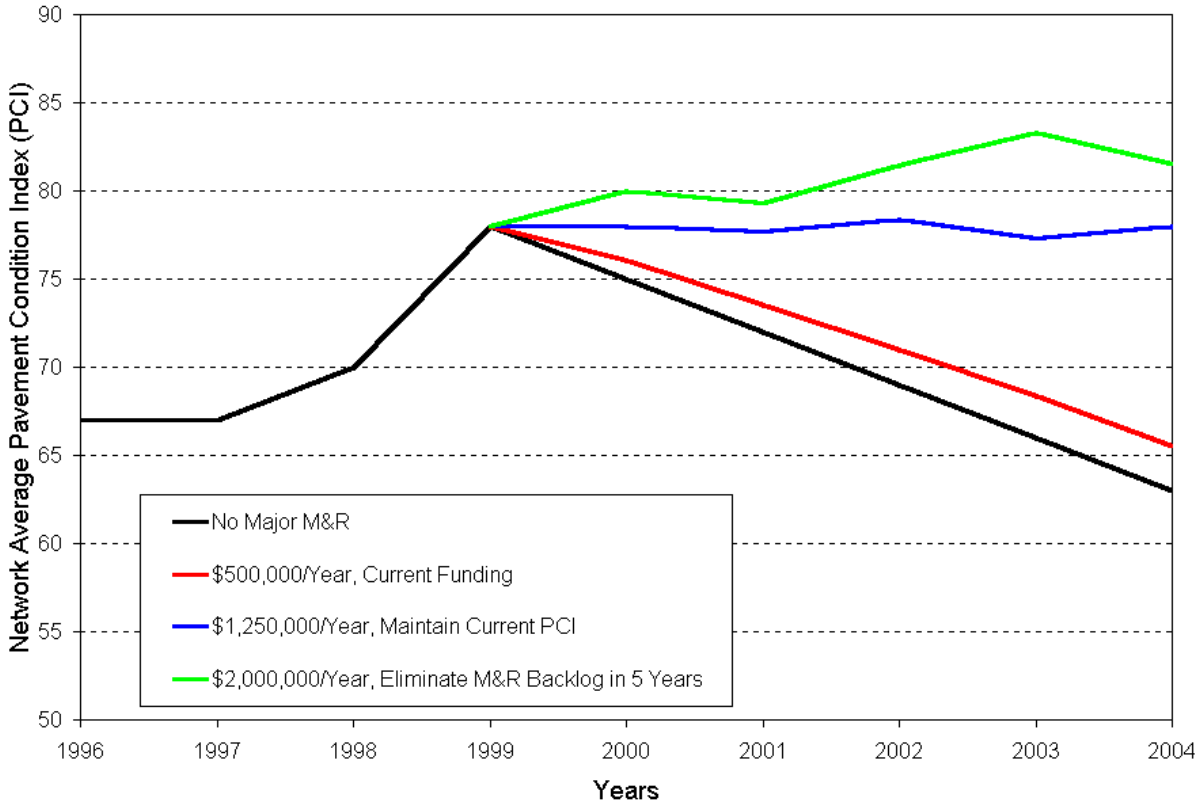

Figure 10

2.5.1 Considering the Effect of Applying Preventive M&R in Work Planning

In multi-year work planning, a pavement section may receive different or repeated M&R based on its condition, rate of deterioration, and length of the work plan period. Applying major M&R will increase the PCI of the pavement section to 100. Applying global preventive

or localized preventive M&R is likely to increase the life of the pavement section. Applying localized safety M&R is not likely to increase the life of the pavement.

2.5.1.1 Considering the Effect of Global Preventive M&R (Surface Treatments) In Work Planning

Two approaches to credit the application of global preventive M&R were investigated. The first approach was to increase the PCI at the time of application and calculate the increase in life. This approach was not recommended since increasing the PCI by few points can lead to an increase in life from one year to over 10 years based on the family deterioration curve. The second and used approach is to specify the increase in pavement life (ΔT) for each type of global preventive M&R and calculate the effective increase in PCI. The calculated increase in PCI will depend on the family deterioration curve assigned to the section. For example, if the PCI of the section at the time of application was 75 and the increase in life is 4 years, then the increase in PCI will be calculated so that the PCI will return 75 in 4 years (Figure 11).

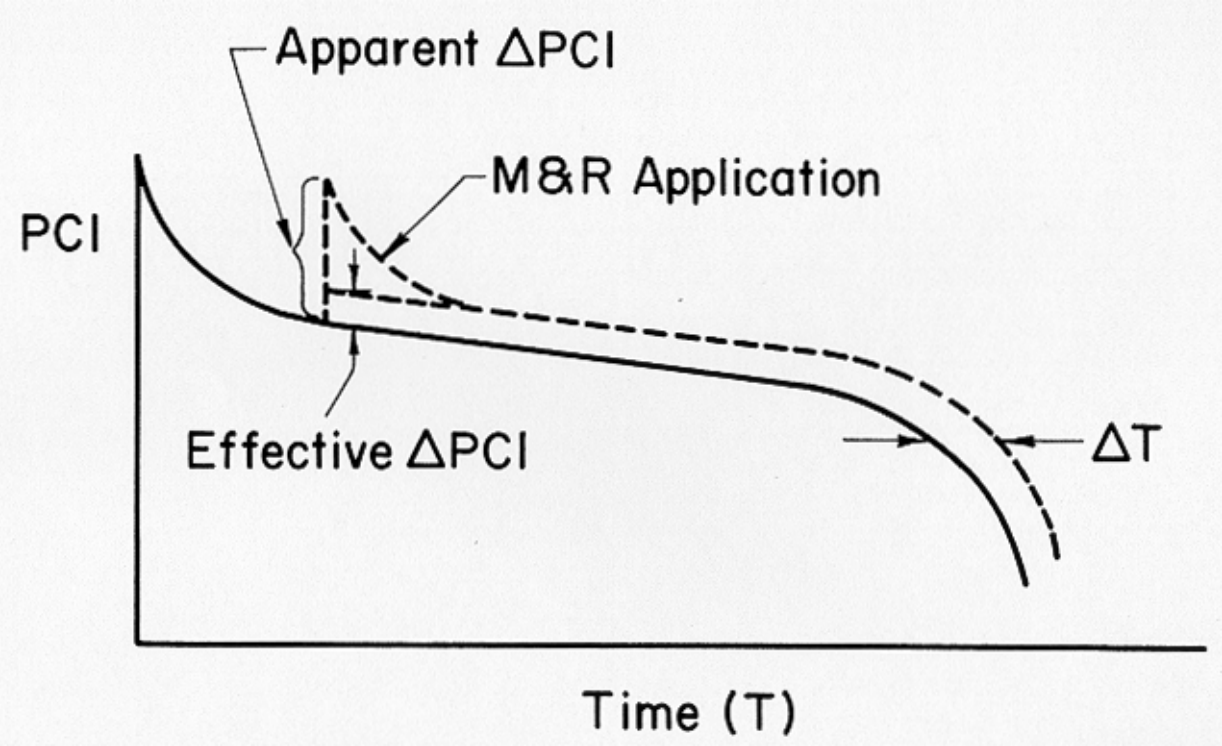

Figure 11

2.5.1.2 Considering the Effect of Localized Preventive M&R in Work Planning

The credit from applying localized preventive M&R can be treated in an approach similar to global preventive M&R method. The application of localized preventive M&R is not likely to start until several years after the last construction or major M&R date. That is normally when crack filling and patching may be required. To credit the performance of the pavement section, one has to specify the expected total increase in life (ΔT). The specified increase can be assigned based on the maintenance agency distress maintenance policy and the type, use, and rank of the pavement section. The annual increase in life (Δt) is calculated by dividing ΔT by the number of years (n) during which the localized preventive M&R is applied.

There is no annual increase during the early years when no localized preventive M&R is applied (Figure 12).

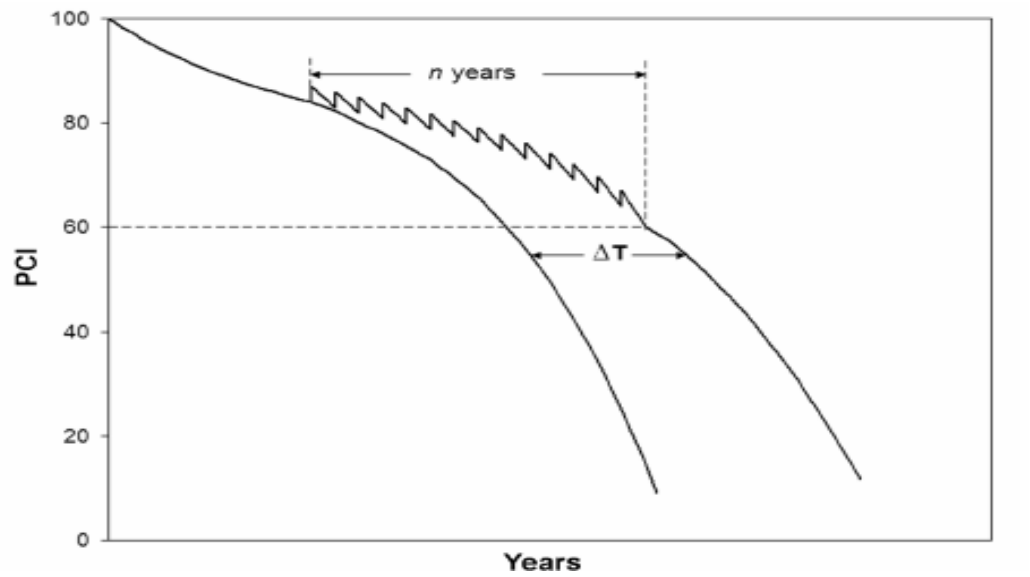

Figure 12

Another important consideration when applying the credit is whether the condition deterioration family curve has built into it the localized preventive M&R policy. If the policy is already built in, then no increase in life should be credited. Also, in this case if the localized preventive M&R is not included in the work plan, then a negative credit should be applied.

2.5.2 M&R Category (Localized/ Global/ Major) Assignment To Pavement Sections

Assigning an M&R category is a function of whether the section PCI is above or below the critical PCI. If the section PCI is above critical, localized preventive and/ or global preventive M&R are applied. Major M&R is applied only if the pavement section is structurally deficient. If the section PCI is below critical, localized safety or major M&R is applied. No preventive M&R is applied (Figure 13).

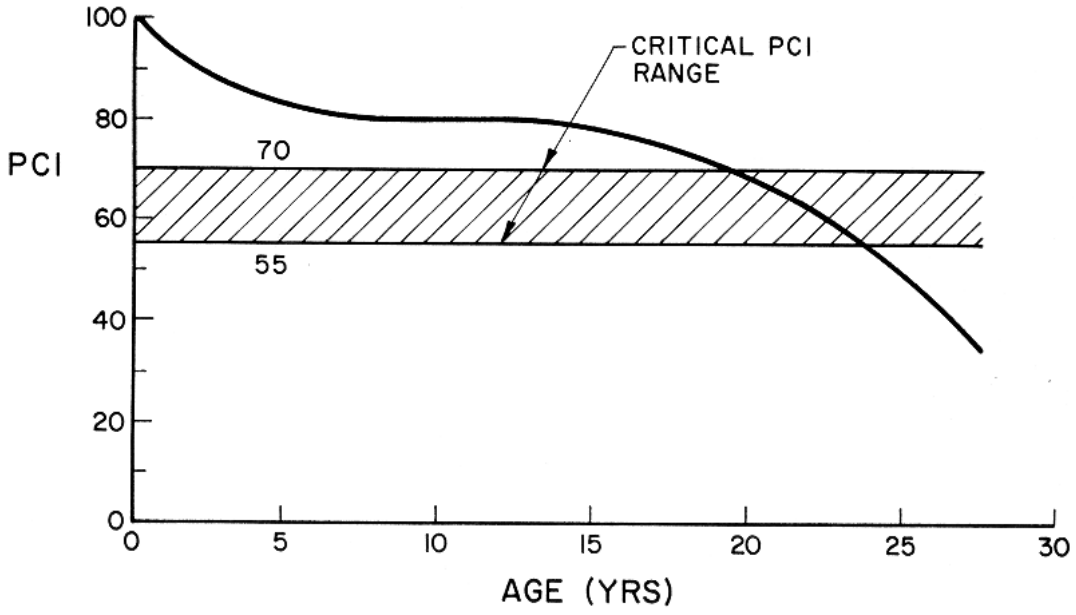

Figure 13

2.6 PROJECT PLANNING

The Project Planning tool in MicroPAVER™ allows the user to develop projects based on user-specified required work and MicroPAVER™ recommended work. This tool greatly aids the user in planning projects and, upon completion of the projects, to automatically update the work history data.

The results of the budget analysis include the recommended M&R category for each pavement section for each year. Because of the economy of scale, it is unlikely that a project will be generated for each pavement section. Instead sections will be grouped to formulate projects that will reduce unit cost and minimize interruption to traffic. The use of GIS (built into MicroPAVER™) is very helpful in formulating projects. When formulating projects, work is specified in terms of M&R type (e.g. 3 inch overlay or surface reconstruction) rather than M&R category (e.g. global or major M&R). Each project is defined as follows:

1. Select a project name
2. Select pavement sections to be included in the project
3. Select M&R types to be performed and assign work date and
4. Add/ delete work items for individual sections if different from the rest of the sections

Projects can be formulated before or after reviewing the results of the budget analysis. The formulation process is the same for either. Once projects have been formulated, the budget consequence analysis can be re-executed and the resulting annual budget variations analyzed in terms of annual deficit and surplus. When re-executing the budget consequence analysis, the previous M&R category assignment to a pavement section are adjusted based on the timing of the project in which the section was included. The formulated projects can be displayed in MicroPAVER™ using GIS.

3 CONCLUSION

This paper presented an overview of the use of MicroPAVER™ for pavement management with emphasis on condition prediction, condition analysis, budget planning, and project formulation and planning. A complete and comprehensive description of all the MicroPAVER™ system capabilities can't all be included in one paper. The following references are provided for further information.

REFERENCES

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