

Overview of the Mobility Pavement Management System (MPMS)

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Prepared for

Washington State Counties

February 9, 2012

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Section 1

Introduction

The concept of a Pavement Management System (PMS) is to achieve the optimum network pavement condition with the funds available. It was with this in mind that the Washington State Department of Transportation (WSDOT), in conjunction with the University of Washington, the Federal Highway Administration, and others, began to gather and analyze data in the 1970s to develop a PMS. Years of research have shown that pavement deterioration can be predicted by a systematic pavement rating process. Research has also shown that preventative maintenance performed at the right time can be up to twelve times less expensive than letting pavement deteriorate to the point where a more expensive rehabilitation must be performed.

In the 1980s, the Washington State County Road Administration Board (CRAB) worked with WSDOT to bring WSC2 PMS (Washington State, City, and County Pavement Management System) to the counties. Several counties implemented a PMS program at that time. When the Washington State Legislature established the County Arterial Preservation Account (CAPA) and the County Arterial Preservation Program (CAPP) in 1990, one of the criteria was that "... a pavement management system is used." (RCW 46.68.095(4)) CRAB later adopted WAC rules for the administration of the CAPP including "WAC 136-70: Pavement Management System Requirement for County Arterial Preservation Eligibility." This WAC requires all counties to use a PMS to guide the pavement preservation and rehabilitation activities on all county paved arterial roads in order to receive CAPP funds. This requirement would not take effect until CRAB provided a PMS computer program for counties to use.

In 1993 CRAB released the County Pavement Management Planning System (CPMPS), a PMS module in the County Road Information System (CRIS) provided to counties. In 2004 CRAB replaced CRIS with Mobility which implemented its own PMS module referred to as Mobility PMS or MPMS.

The PMS strategy applied in MPMS consists of four major parts:

1. **Surface Conditions** – Recording visible distresses on the pavement surfaces, which are calculated into a Pavement Structural Condition (PSC) score.
2. **Generate Project File** - Define a road system as a rational set of projects.
3. **When Analysis** - Formulate a Pavement Performance Curve to predict the PSC score for each project segment.
4. **What Analysis** - Define and apply a budget and strategy, comparing the results of multiple iterations to determine the best course of action.

The remaining sections of this paper will describe the four major parts of the MPMS strategy in detail.

Section 2

Surface Conditions

“Regularly scheduled pavement condition inspection is one of the most important steps in implementing a comprehensive Pavement Management System.” (Group & Kay, 1992)

Mobility collects and organizes pavement condition inspections into Surface Condition segments. Surface Condition segments are identified by the Road Log number, “from” and “to” mileposts, lanes rated, and rating date. The severity and extent of up to 12 visible distresses can be recorded for flexible pavement types (8 for rigid pavement types).

Mobility automatically calculates a Pavement Structural Condition (PSC) score for each Surface Condition segment. The PSC formula uses the severity and extent recorded for Transverse, Longitudinal, and Alligator cracking as well as Patching to calculate one score for each Surface Condition segment. The PSC formula is:

$$PSC = 100 - 15.8 (EC)^{0.5}$$

where

PSC = Pavement Structural Condition

EC = equivalent cracking, which is a composite of alligator, longitudinal, transverse cracking, and patching.

The EC is an additive function as follows:

$$EC = ACEC + LCEC + TCEC + PTEC$$

where

EC = total equivalent cracking

ACEC = alligator cracking component of equivalent cracking

LCEC = longitudinal cracking component of equivalent cracking

TCEC = transverse cracking component of equivalent cracking

PTEC = patching cracking component of equivalent cracking

The above information as well as additional information on how to calculate ACEC, LCEC, TCEC, and PTEC is documented in Appendix E of the document *“The WSDOT Pavement Management System - A 1993 Update”* noted in the “Works Cited” section of this document.

To assist in scheduled pavement condition rating CRAB has developed a software package called VisRate. VisRate can be installed on laptops and used in the field by pavement raters to efficiently record pavement distresses. After pavement raters have finished collecting data, VisRate can upload the data to the Mobility database, transforming the information into rating segments.

Using the pavement condition rating information stored in Mobility, the MPMS can better predict pavement performance as detailed in Section 4 of this document.

Section 3

Generate Project File

The MPMS project generation step creates project segment records for all paved road surfaces as identified in the Mobility Road Log. Project records are segmented based on the project generation settings: maximum project length, default pavement year, and jurisdiction(s) to include. Road Log segments can also be excluded from the project generation step by checking the **“Exclude From PMS”** option on the **“Structure”** tab of the Road Log segment data entry form. Additionally, pavement management projects are not generated for sections of road that have already been scheduled for a project (e.g., 6 year T.I.P.). These projects can be identified in the **“Planned Projects”** inventory so that they are excluded from Mobility PMS.

“Maximum Project Length” is used to limit the project length when other Road Log characteristics otherwise would not. For example, a road has two one mile Road Log segments. These segments are identical with the exception that segment 1 has no sidewalks and segment 2 has a left sidewalk. Since sidewalk is not a characteristic evaluated in Mobility PMS then generating a project file with a maximum project length of 2 miles will result in one project segment on this road. If a county decides that projects should be managed with a maximum project length of 1 mile then two project segments would be created for this road.

“Default Pavement Year” is used when the **“Pavement Year”** in the Road Log record is blank. Pavement year is a **critical field** when projecting pavement condition in the When Analysis phase described later in this document.

The following Road Log fields are evaluated and could result in a project segment shorter than the specified maximum project length are: **“Surface”**, **“Pavement Year”**, **“Top Layer Thickness”**, **“Federal Function Class”**, **“# of Thru Lanes”**, **“Length”**, **“ADT Volume”**, and **“Truck Route Class”**. All of these Road Log fields are used during the subsequent When Analysis and What Analysis. If the values of any of these fields differ for contiguous Road Log segments, separate project segments are created.

Section 4

When Analysis

The When Analysis phase of MPMS statistically formulates the Pavement Performance Curve (PPC) used to predict a Pavement Structural Condition (PSC) score for a project segment. The When Analysis is also the point in MPMS to indicate whether or not to use Non Destructive Testing (NDT) data and/or Ride data.

The process of determining the PPC used for a project begins by identifying four critical pieces of data:

1. Surface Condition Records
2. **“Pavement Year”**
3. **“Top Layer Thickness (in.)”**
4. Thru Lane **“Surface”**

Surface condition records can be analyzed in one of two ways: **Standard** or **Complete**. The **Standard** method will use all surface condition records that intersect a project segment since the segment was last paved as determined by **“Pavement Year”** in the Road Log. The **Complete** method will use ALL surface condition records that intersect a project segment.

A default PPC is selected based on the **“Surface”** and **“Top Layer Thickness (in.)”** of a project segment as determined from the Road Log. The formula for a PPC is:

$$PSC = C + (mA^P)$$

where

PSC = Pavement Structural Condition rating

A = Age which represents the time since construction or the last resurfacing (years)

C = model constant for maximum rating (~ 100)

M = slope coefficient

P = “selected” constant that controls degree of curvature of the performance curve

(Kay, Mahoney, & Jackson, 1993)

For example, a project segment with a **“Surface”** of ACP and a **“Top Layer Thickness (in.)”** of 1.5 would result in the following PPC formula:

$$PSC = 100 + (-0.23 * (AGE^{2.25}))$$

The values for the PPC variables (Constant, Slope Coefficient, and Curve Exponent) are stored in the projection curves lookup table. This table can be modified by each county as necessary.

The next step in the When Analysis determines if any surface condition records exist for a project segment. If no surface condition records exist then the default prediction curve is used. If however, surface condition records do exist, the When Analysis begins a process of nonlinear regression to determine the formula for a "Best Fit" PPC. During this process the program substitutes a number of different exponents (P) to transform the independent variable, age. The "Best Fit" is determined by the formula with the highest R² value (coefficient of determination) and lowest RMSE (root mean square error) using the least sum of squares method. The regression statistics are explained in detail in Appendix B of the report titled "The WSDOT Pavement Management System – A 1993 Update" referenced in the "Works Cited" section at the end of this document. (Kay, Mahoney, & Jackson, 1993)

As mentioned earlier, When Analysis is also where it is decided whether to include NDT and/or Ride data. To include NDT data select either "**Yes (average)**" or "**Yes (worst)**". If "**Yes (average)**" is selected a weighted average is calculated for all structural condition records that intersect the project segment. If "**Yes (worst)**" is selected the lowest value of the structural condition records that intersect the project segment is used.

In addition to choosing whether to use a weighted average or only the worst value, it must be decided to use either inches of roughness per mile or CAAMS Ride Index when including Ride data. To choose inches of roughness per mile select "**Yes (Average In/Mile)**" or "**Yes (Worst In/Mile)**". To choose CAAMS Ride Index select "**Yes (Average CAAMS)**" or "**Yes (Worst CAAMS)**".

Section 5

What Analysis

The final stage of MPMS is the What Analysis. The What Analysis predicts the rehabilitations to be performed for each project segment. As with every stage of MPMS some preparation may be required.

First, review and update the rehabilitation list. The rehabilitation list can be accessed from the menu **“Admin” -> “Pavement Rehabilitations”**. The rehabilitation list contains rehabilitations available to the MPMS decision trees. When defining rehabilitations, provide a **“Rehabilitation Description”**, **“Existing Pavement Type”** (what pavement types the rehabilitation can be used on), **“Cost (dollars per lane mile)”**, **“Projected Life (years)”**, the **“Resulting PSC”**, and the **“Resulting Pavement Type.”**

Second, review the **“Defined Values”** lookup table. In this table values for Should, Must, and SMBP (Should Must Break Point) are defined. These values are critical in the What Analysis. No rehabilitations will be performed on projects with a PSC greater than the Should level, and no rehabilitations will be performed on projects with a PSC less than the Must level.

Lastly, review and update the Decision Tree(s). Decision Trees are a collection of rules that will determine what rehabilitation is selected (if any) for each project segment. Multiple Decision Trees can be created for organizational and comparison purposes. Create a new decision tree by navigating to **“PMS” -> “Decision Trees” -> “Edit Decision Trees...”** Review and update the rules for the decision tree to be used in the What Analysis by navigating to **“PMS” -> “Decision Trees” -> “Edit Decision Tree Rule Collections...”**

After completing the initial setup described above the What Analysis can be run. The first step is to define the **“Strategy.”** Under **“Strategy,”** select the decision tree to use, the year to start the What Analysis, the repair order, and the function class order (optional). The repair order options are either **“Best First”** or **“Worst First.”** The decision to use **“Best First”** or **“Worst First”** is only important when running the What Analysis with a limited budget. Budget constraints may result in less than 100% of projects being selected for rehabilitation (that SHOULD be selected for rehabilitation). The repair order gives priority to either the projects with the highest PSC (Best First) or the lowest PSC (Worst First). Function class order can be used to further give preference to projects when working within a limited budget.

Next, decide what budget option to use:

1. Budget Option 1: This budget option has unlimited funds. Input the number of years to run the What Analysis and all projects will have a rehabilitation applied according to the decision tree. After the What Analysis completes, an estimated total cost to rehabilitate the entire road network is calculated and displayed on the screen.

2. Budget Option 2: This option requires the number of years to run the What Analysis and the budget amount available each year. Only one budget amount is input and this same budget amount is used each year. Rehabilitation projects are selected for each year until no funds remain, or all predicted rehabilitations are completed.
3. Budget Option 3: This budget option is similar to budget option 2 in that it also has a limited budget. One difference is this budget option is run for exactly six years. Also, this budget option allows a unique budget to be set for each of the six years.

After defining a strategy and budget run the What Analysis. If the decision tree used for What Analysis does not include a valid rehabilitation for a project segment that is at or below the “Should” level, a report titled “Tree Error” will be displayed. Review this report to determine what changes need to be made to the selected decision tree. If a scenario exists where a project should not be rehabilitated when its’ PSC is between the Should and Must level, create a rehabilitation called “Do Nothing” and assign it a set of rules in the decision tree. This “Do Nothing” rehabilitation type helps to identify projects that have been intentionally ignored, and not mistakenly left off the decision tree.

After the What Analysis is completed several reports are available under “**Reports**” -> “**Pavement Management.**” Use these reports to evaluate the predicted network condition and the recommended project rehabilitations.

Section 6

Works Cited

Group, N. P., & Kay, R. K. (1992). *Pavement Surface Condition Rating Manual*. Washington State Printing Office.

Kay, R. K., Mahoney, J. P., & Jackson, N. C. (1993). *The WSDOT Pavement Management System - A 1993 Update*. Seattle: Washington State Transportation Center.