DISTRICT LEVEL DECISION MAKING TOOL FOR PREVENTIVE MAINTENANCE TREATMENT SELECTION IN VIRGINIA

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Original Submission Date: August 1, 2013
Word Count:
Abstract: 185
Text: 4,473
Figures and Tables: 2,500
ABSTRACT

Preventive maintenance has the potential to improve network condition by retarding future pavement deterioration. The Virginia Department of Transportation uses its pavement management system to determine maintenance targets for each district. The districts then use these recommendations to select pavements that will receive maintenance and the types of treatments that will be applied. Each district has a different approach to preventive maintenance. There was a need for more consistent preventive maintenance practices across the state.

This paper outlines the development of a district level preventive maintenance treatment selection methodology. The methodology proposed includes preparing a prioritized list of pavement sections, and selecting the projects that maximize the cost-effectiveness of the selected treatments subject to budgetary constraints set by the central office. To illustrate the application of the methodology, it was implemented in a prototype treatment selection tool and was run for each pavement classification in each district. The results were encouraging and suggested that the selection tool has the potential to be a very powerful decision support tool if the unit costs are representative of what the expected treatment costs are for each district.
INTRODUCTION

Preventive Maintenance
Maintaining road conditions to acceptable standards can be quite costly with traditional rehabilitation-based pavement maintenance approaches (1). Pavement preservation can be defined as “a program employing a network level, long-term strategy that enhances functional pavement performance by using an integrated, cost-effective set of practices that extend pavement life, improve safety, and meet motorist expectations” (2).

Pavement preservation is a general category of road maintenance which consists of three components: minor rehabilitation, routine maintenance, and preventive maintenance (2). Although the terms “pavement preservation” and “preventive maintenance” are often used interchangeably, preventive maintenance is in fact a subset of pavement preservation. The concept of preventive maintenance involves maintaining the functional condition of roadway systems without improving their structural capacity by strategically applying cost-effective treatments (3). Preventive maintenance seals the pavement surface and prevents water from infiltrating into the pavement structure.

Preventive maintenance is being promoted so that pavements can still benefit from reduced levels of funding—state departments of transportation simply cannot afford to do the same levels of maintenance and rehabilitation that have been carried out in the past (4). This concept is illustrated in Figure 1, where PM, CM, RM, and RC represent Preventive Maintenance, Corrective Maintenance, Restorative Maintenance, and Rehabilitation and/or Reconstruction, respectively.

Possible preventive maintenance treatments include crack seals, slurry seals, chip seals, microsurfacing, cape seals, and thin and ultra-thin hot mix asphalt overlays. Brief descriptions of these treatments are presented following.
**Crack Seal**
Crack seals are defined as the placement of an adhesive material into or over working cracks for the main purpose of preventing the infiltration of moisture into the pavement (6).

**Slurry Seal**
A slurry seal may be defined as a mixture of well-graded fine aggregate and asphalt emulsion (7).

**Chip Seal**
A chip seal may be defined as a sprayed application of asphalt followed by the application of aggregate chips which are immediately rolled to achieve 50% to 70% embedment. A chip seal may be applied in a single layer or a double layer where a layer of large aggregate is placed first, followed by a layer of smaller aggregate (6).

**Microsurfacing**
Microsurfacing is a mixture of crushed, well-graded aggregate, mineral filler, and latex-modified asphalt that is placed on the pavement surface with a squeegee or spreader box (6).

**Cape seal**
A cape seal is a combination of a chip seal and a slurry seal (or, alternatively, microsurfacing). The slurry seal is placed above the chip seal approximately 4 to 10 days after the initial chip seal application. The cape seal is used for the same purpose as a chip seal, however, the slurry seal extends the life of the chip seal since it forms a protective layer over it that improves the binding of the aggregate chips (6).

**Thin and Ultra-Thin Hot Mix Asphalt Overlay (THMACO)**
These overlays are composed of asphalt binder and aggregate combined in a paving machine and laid on an existing pavement (milled or unmilled). These overlays can be gap-graded, dense-graded, or open-graded (7). These overlays are typically less than 1.5 inches thick (6).

**Pavement Management Systems and Preventive Maintenance**
The American Association of State Highway and Transportation Officials (AASHTO) defines pavement management as “a management approach used by personnel in an agency to make decisions” and a pavement management system (PMS) as “a set of tools used to assist decision-makers at all levels in making better and more informed decisions” (8). The network-level decision making process has become more efficient with the advent of pavement management systems. A PMS provides a centralized database that can be used to store pavement data, analyze past pavement performance, predict future pavement performance, recommend maintenance strategies, and forecast the effect of different types of maintenance on network level performance. It allows highway agencies the means to justify maintenance strategies to external entities such as state and federal officials or the general public. It also has the ability to strategically improve network condition over time through managed long-term goals.

A PMS is an important tool in the development of preventive maintenance policies. A PMS can demonstrate the key benefit to preventive maintenance: preventing potentially costly rehabilitation by maintaining good pavement condition. One possible benefit of integrating PMSs with preventive maintenance is the possibility for prioritization and optimization within...
the pavement management process. Preventive maintenance operations can be run in tandem
with major rehabilitation so that poor pavements are improved while good pavements maintain
their good condition. It should be noted, however, that performance of preventive maintenance
treatments should be monitored so that prediction models can be refined and their expected
benefit specific to the desired road network can be estimated (9).

OBJECTIVE

This paper documents the development of a decision support methodology and supporting tool
that can be used to promote effective selection of preventive maintenance treatments within a
transportation agency. This work was performed at the Virginia Tech Transportation Institute as
part of a project sponsored by the Virginia Department of Transportation (VDOT) to identify the
best practices for implementation of a preventive maintenance program and to monitor the
performance of preventive maintenance treatments within the state.

BACKGROUND

Virginia Department of Transportation Current Maintenance Practices

VDOT uses three condition indices to rate pavement distresses in Virginia. The first index is the
Load-Related Distress Rating (LDR) which measures pavement distresses which are load-
related. The second index is the Non-Load-Related Distress Rating (NDR) which measures
pavement distresses which are not load-related, such as those caused by environmental or
climatic conditions. These two condition indices are rated on a scale of 0 to 100, where 100 is a
pavement having no distresses present. The third index is the Critical Condition Index (CCI)
which is the lower of the LDR and NDR (10). All interstate and primary pavements in Virginia
are rated using continuous imaging; distresses are collected using automated data collection
methods. VDOT defines a deficient pavement as one which has a CCI value below 60. The
statewide target for Interstate and Primary route condition is to have ≤ 18% of these pavements
rated deficient (11).

Each district has different levels of pavement deficiency. Many factors can affect
pavement condition, such as budget, policies, traffic, climate, etc. There is currently no statewide
standard for an accepted preventive maintenance policy. Through speaking to pavement
managers at three district visits, it was found that Salem district applies preventive maintenance
to pavements with a CCI greater than 85, Richmond district applies preventive maintenance to
pavements with a CCI between 75 and 85, and Northern Virginia (NOVA) district applies
preventive maintenance to pavements with a CCI between 80 and 89. This disparity in
preventive maintenance policy is potentially a contributing factor to differences in pavement
performance among districts.

The Virginia Department of Transportation Pavement Management System

VDOT currently uses a PMS developed by AgileAssets (12). This system performs network-
level unconstrained and multiconstraint optimization. The output of the unconstrained
optimization analysis is the recommended treatment category for each section: Do Nothing
(DN), Preventive Maintenance (PM), Corrective Maintenance (CM), Restorative Maintenance
(RM), or Rehabilitation and/or Reconstruction (RC). The multiconstraint analysis develops a
work plan using single objectives and multiple constraints. The objective can be either to
minimize cost while achieving specified performance targets, or to maximize benefit while satisfying budgetary concerns.

The VDOT Central Office generates reports from the PMS multiconstraint analysis that provides maintenance targets for each district. District budgets and numbers of lane miles are provided for each maintenance category (PM, CM, RM, RC). The district pavement manager uses these recommendations along with the unconstrained analysis to decide which pavements are selected for maintenance and which treatments are applied. Over time, each district has developed its own preventive maintenance policy, and there is a statewide disparity regarding preventive maintenance treatment selection. Districts have different criteria that can qualify a pavement for consideration for preventive maintenance, and treatment selection is based upon engineering experience. Specific guidelines for the use of preventive maintenance are needed.

DISTRICT VISITS AND DOCUMENTATION OF IN-STATE PRACTICES

General Observations

A comparison of treatment placement across districts and the CCI triggers for preventive maintenance are shown in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>District</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Salem</td>
</tr>
<tr>
<td></td>
<td>Richmond</td>
</tr>
<tr>
<td></td>
<td>Northern Virginia</td>
</tr>
<tr>
<td>Crack Seal Placement</td>
<td>Primary and Interstate</td>
</tr>
<tr>
<td></td>
<td>Interstate</td>
</tr>
<tr>
<td></td>
<td>Primary and Secondary Roads</td>
</tr>
<tr>
<td>Slurry Seal Placement</td>
<td>Secondary Roads (150 – 200 vehicles per day)</td>
</tr>
<tr>
<td></td>
<td>Primary and Secondary Roads</td>
</tr>
<tr>
<td></td>
<td>Primary and Secondary Roads</td>
</tr>
<tr>
<td>Microsurfacing Placement</td>
<td>Primary and Interstate</td>
</tr>
<tr>
<td></td>
<td>Primary Roads</td>
</tr>
<tr>
<td></td>
<td>--</td>
</tr>
<tr>
<td>Chip Seal Placement</td>
<td>Secondary Roads (&lt;150 vehicles per day)</td>
</tr>
<tr>
<td></td>
<td>Secondary Roads</td>
</tr>
<tr>
<td></td>
<td>--</td>
</tr>
<tr>
<td>Cape Seal Placement</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>Secondary Roads</td>
</tr>
<tr>
<td></td>
<td>--</td>
</tr>
<tr>
<td>CCI Triggers for PM</td>
<td>85 – 100</td>
</tr>
<tr>
<td></td>
<td>75 – 85</td>
</tr>
<tr>
<td></td>
<td>80 – 89</td>
</tr>
</tbody>
</table>

The recommendations provided by the VDOT Central Office are for general maintenance categories, and districts must select the specific treatment types and which pavement sections should be selected based on district experience and judgment. After reviewing the responses received from the Salem, Richmond, and Northern Virginia districts, it was found that each district developed its own preventive maintenance policy over time. Each district has different criteria for placement of these preventive maintenance treatments. For example, slurry seals are placed on primary and secondary roads in Richmond and Northern Virginia, but only on secondary roads in Salem. Microsurfacing is used on interstate and primary roads in Salem, but only on primary roads in Richmond. Northern Virginia applies slurry seals to primary and
secondary roads, but does not use microsurfacing. Additionally, the CCI triggers for preventive maintenance vary between districts.

This district investigation highlighted the need for a formal preventive maintenance policy that builds upon the central office recommendations using distress type and severity, pavement age, network classification, and traffic to develop preventive maintenance treatment selections that are consistent across districts. The findings from the district investigations were compiled as a report in (13).

RECOMMENDATIONS FOR IMPLEMENTATION OF A PREVENTIVE MAINTENANCE POLICY

The effectiveness of each treatment for specific distress types was obtained from review of literature. It was determined that chip seals and slurry seals in general were not appropriate for use on interstate pavements. Chip seals have an aggregate cover that may become dislodged with traffic traveling at high speeds (7). Slurry seals depend on climatic conditions to break and cure, and their curing time is highly unpredictable (6). Since lane closures on interstate pavements should be minimized, it was decided that slurry seals should not be applied in these cases. The treatment feasibility for the treatments specific to this study were selected based on the pavement age, traffic level, and the distresses used in the VDOT decision matrices: alligator cracking, transverse cracking, rutting, and patching. The treatment characteristics were developed primarily based on those found in a recent SHRP 2 study (6), and these are listed in Table 2.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Expected Life (years)</th>
<th>Type of Network</th>
<th>Pavement Age</th>
<th>Traffic Level</th>
<th>Alligator Cracking Severity</th>
<th>Transverse Cracking Severity</th>
<th>Rutting Severity</th>
<th>Patching Severity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chip Seal</td>
<td>3 – 7</td>
<td>Primary</td>
<td>5 – 8</td>
<td>All</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Slurry Seal</td>
<td>3 – 5</td>
<td>Primary</td>
<td>5 – 8</td>
<td>Low &amp; Medium</td>
<td>Low</td>
<td>Low</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Micro-surfacing</td>
<td>3 – 6</td>
<td>Primary, Interstate</td>
<td>5 – 8</td>
<td>All</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>THMACO</td>
<td>5 – 12</td>
<td>Primary, Interstate</td>
<td>6 – 12</td>
<td>All</td>
<td>Low &amp; Medium</td>
<td>Low &amp; Medium</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

An approach combining expected performance, decision matrix analysis, cost effectiveness, and heuristics was deemed to be the most beneficial for implementation of a preventive maintenance policy in Virginia. Multiple levels of analysis led to the development of a robust methodology and decision support tool.

This treatment selection tool was developed in two parts: feasible treatment identification and the district-wide selection. The framework of the treatment selection tool is presented in Figure 2.

First, the treatment feasibility is established based on the pavement section’s age, traffic level, type of network, and distress type and severity. Next, the benefit of each treatment on each section is calculated. The benefit is calculated as the product of lane miles and the area between the DN and PM curves above a specified benefit cutoff value, shown in Figure 3. This benefit...
cutoff value was assumed to be 60 based on the VDOT deficient pavement criterion: pavements that have a CCI below 60 are considered to be deficient.

FIGURE 2 Overview of treatment selection tool.
The cost of each treatment on each maintenance section is calculated using specified unit costs and pavement area as shown in Equation 1.

\[
\text{Treatment Cost} = (\text{lane miles}) \times (\text{lane width}) \times (\text{unit cost})
\]  

(1)

The cost effectiveness of each treatment on each maintenance section is computed using the Benefit-Cost Ratio (BCR), which, as its name suggests, is the ratio of Benefit to Cost, or Benefit/Cost.

The Marginal Cost Effectiveness method is then used to perform pavement and treatment selection. Each possible combination of pavement section and treatment is listed. For each pavement section, the treatments are sorted in ascending order based on their cost. The increase in cost and increase in benefit are both computed for each new treatment on each section. If there is a negative value for increase in benefit, i.e. a decrease in benefit for an increase in cost, this treatment option is removed from consideration. The MCE is then computed as shown in Equation 2.

\[
\text{MCE} = \frac{\text{(Increase in Benefit)}}{\text{(Increase in Cost)}}
\]  

(2)

The corrected MCE is then computed as the lower value between the treatment’s BCR and MCE. All options are then sorted in descending order based on the corrected MCE. Sections are then selected until the budget is exhausted. While making selections, if there is any new treatment for a section on the list, this treatment is selected for that section and the previous selection for that section is removed. This adjustment is made because there would be a higher benefit achieved even though the cost may have been slightly higher.
These recommendations can greatly benefit engineers at the districts to ensure that near-optimal decisions are being made regarding preventive maintenance.

TREATMENT SELECTION TOOL INPUTS

The tool requires certain user inputs in order to develop recommendations for treatment selection on each section, and to provide a prioritized list of pavements that can be used by the districts to aid in their maintenance activities. The user inputs required for the tool are:

1. Treatment performance
2. Do-Nothing performance
3. Current-condition data
4. Cost data
5. Central Office recommendations for total preventive maintenance lane miles and budget specific to each district.

The treatment feasibility identified in Table 2 was incorporated into the tool. Also, the user is given a choice to either use default do-nothing and treatment performance models as developed in this study, or to input new models.

Treatment Performance

Pavement condition data was obtained from the VDOT PMS to develop treatment performance models for preventive maintenance on asphalt pavements (BIT). The performance of four preventive maintenance treatments were considered based on condition data obtained for interstate and primary systems for: chip seals, slurry seals, microsurfacing, and THMACO.

Microsurfacing had the largest dataset with 1,363 records available. There were 362 records available for slurry seal, 63 records available for chip seal, and 22 records available for THMACO. Some sections had CCI values of -1, suggesting that the data for these sections was not collected. These null sections were removed. After inspecting the data, it was seen that pavement condition seemed to increase after 10 years. This was attributed to the possibility of treatments being applied to pavements without being recorded. Pavements older than 10 years were therefore not considered in the analysis. Since the microsurfacing dataset was so large, this data was divided according to type of network: interstate or primary.

Based on recommendations from VDOT central office personnel, an outlier analysis was performed to remove any outliers in the data. Pavement sections with unusual performance were removed so that they did not influence the model.

Linear regression was then performed to obtain the expected performance of each preventive maintenance treatment. The linear model allows for a general computation of benefit with minimal reduction in the accuracy provided by more complex models. A sample comparison between the accepted VDOT model and a linear model is shown in Figure 4a. This comparison shows that the linear model is an adequate representation of expected pavement performance expressed by the VDOT model. The linear deterioration models are shown in Figure 4b, and they are listed in Equations 3 through 7.
Microsurfacing (Interstate):  
\[ CCI = 100 - 4.7954 \times \text{Age} \]  
(3)

Microsurfacing (Primary):  
\[ CCI = 100 - 6.3780 \times \text{Age} \]  
(4)

Slurry Seal:  
\[ CCI = 100 - 4.9392 \times \text{Age} \]  
(5)

Chip Seal:  
\[ CCI = 100 - 3.8905 \times \text{Age} \]  
(6)

THMACO:  
\[ CCI = 100 - 0.8422 \times \text{Age} \]  
(7)

Do Nothing (Base) Models

Models were available from VDOT for each pavement system, each type of pavement, and each type of last performed maintenance. The default model was assumed to be the CM model. A
linear approximation of this model was obtained for Interstate and Primary routes on BIT
pavements. These linear do-nothing models are expressed in Equation 8 for interstate routes and
Equation 9 for primary routes.

\[
\begin{align*}
\text{CCI} &= 100 - 5.20 \times \text{Age} \\
\text{CCI} &= 100 - 3.80 \times \text{Age}
\end{align*}
\]

\(8\)  \(9\)

**Current Condition**

The current pavement condition was obtained from the PMS for each district. Eligible candidates
for preliminary consideration for preventive maintenance included all pavements from the PMS
unconstrained analysis that were recommended for PM on BIT pavements.

**Cost**

Cost estimates were obtained from VDOT for each of these treatments. The approximate cost per
lane mile is shown in Table 3.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost per Lane Mile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chip Seal</td>
<td>$8,839</td>
</tr>
<tr>
<td>Slurry Seal</td>
<td>$13,376</td>
</tr>
<tr>
<td>Microsurfacing</td>
<td>$16,620</td>
</tr>
<tr>
<td>THMACO</td>
<td>$33,077</td>
</tr>
</tbody>
</table>

**Central Office Recommendations**

The VDOT Central Office provides recommendations for each district regarding recommended
lane miles for each maintenance type (PM, CM, RM, RC) and the budget available for these
recommendations.

**DISTRICT-WIDE SELECTION: RESULTS AND ANALYSIS**

The treatment selection tool was developed using the methodological framework summarized in
Figure 2. Computations were automated, and the tool provided output regarding all possible
feasible treatments, the cost effectiveness of treatments, and the pavement and treatment
selections for the district based on the MCE computations. Sample screenshots of the input
windows are presented in Figure 5.
For illustration purposes, the prototype treatment recommendation tool was run for each district and each roadway classification (interstate and primary) to obtain a prioritized list of pavement sections and their respective treatments. The implementation of the model will require fine tuning the deterioration models and refining the inputs (treatment costs, etc.)

There were two main treatments that were recommended by the selection tools: chip seal and THMACO. After reviewing the models that were developed, it was seen that these two treatments had the slowest expected rate of pavement deterioration when compared to slurry seal and microsurfacing. There were considerably less data points for chip seal and THMACO than there were for slurry seal and microsurfacing. The limited sample of pavements that received these treatments had a relatively good response to these treatments. The slurry seal and microsurfacing treatments had a much larger dataset, and there was a high level of variability within the data. It is important to note that the potential benefit of these treatments may not have
been represented by these models, and a comprehensive data review is recommended to be carried out at the district level.

A summary of the analysis results as compared to the results of the VDOT unconstrained analysis is shown in Figure 6.

**FIGURE 6** Comparison between decision tool results and central office unconstrained analysis results for (a) lane miles and (b) budget.

In cases where the decision tool budget recommendations were significantly lower than the central office budget, there were insufficient sections that were recommended for preventive maintenance. In these cases, the pavement age was either too low or too high.
The expected cost per lane mile of the preventive maintenance category is computed as a weighted average of the lowest bid prices from the previous year, adjusted for inflation. The preventive maintenance treatments most frequently used in Virginia are currently crack sealing and patching. The weighted estimate of preventive maintenance developed by the central office therefore does not reflect the cost of surface applications such as the four treatments identified in this study.

After comparing the calculated treatment costs for each pavement section in the analysis to the expected cost for each treatment based on the PMS computations, it was seen that the cost for the preventive maintenance category was approximately equal to the cost of chip seal. For pavements that were assigned THMACO, the calculated treatment costs were approximately four times higher than the cost for the preventive maintenance category. Based on the expected performance, in most cases, THMACO yielded the highest benefit and THMACO was therefore assigned to most sections. Since the cost of a THMACO is almost four times the expected cost of the preventive maintenance treatment category, only about one quarter of the recommended lane miles were selected for maintenance.

**VERIFICATION**

The results obtained using the MCE method for Bristol interstate routes were compared to a true optimization method using an integer program outlined in Equation 10 through 17.

\[
\begin{align*}
\text{Max } z &= \sum x_i b_i/c_i \\
\text{Subject to} & \\
\sum x_i c_i &\leq p \\
\sum x_i i &\leq q \\
x_i &= 1 \text{ if section } i \text{ is selected; 0 otherwise}
\end{align*}
\]

Where

- \( b_i \) = benefit of section \( i \)  \\
- \( c_i \) = cost of section \( i \)  \\
- \( p \) = recommended budget for PM  \\
- \( q \) = recommended lane miles for PM

The integer program was set up in Microsoft Excel and the Solver Add-in was used to determine an optimal solution. A comparison of the results of the MCE method and the integer program solution are shown in Figure 7.

The total cost of PM treatments and the respective lane mile recommendations developed using the MCE method were marginally lower than the results obtained from the true optimization. In many cases, instead of selecting one section with a high cost-benefit ratio, the optimization method selects multiple sections, each having a lower cost-benefit ratio. The sum of the cost benefit ratios of the multiple-section-selection exceeds the cost benefit ratio of the single section. The true optimization method therefore has the ability to exhaust more of the budget, by selecting sections that may have a lower priority because of their cost-benefit ratio.
Although the integer program methodology provides an optimal selection of pavement sections for preventive maintenance, it is difficult to implement an optimization procedure into an automated tool using the available Microsoft Excel Solver Add-in. This software has a limitation of 200 decision variables. If there are more than 200 pavement sections that are eligible for preventive maintenance in a district, the tool would not work. The results of the verification, however, show that the MCE method, which is less complex than true optimization, provides comparable recommendations for preventive maintenance.

District personnel can use the tool to identify feasible preventive maintenance treatments for each section. The treatment feasibility capability of the tool is particularly important, because
it would provide consistent recommendations across the state for inputs such as pavement age, traffic level, and distress type and severity. As preventive maintenance treatment performance is monitored over time, the models can be updated. The final pavement section selections made by the tool can then be improved by updating the expected treatment performance specific to each district. The treatment selection tool outlined in this paper is a useful decision support tool that can be immediately implemented in the Virginia maintenance districts.

CONCLUSIONS AND RECOMMENDATIONS

This paper outlined the development of a preventive maintenance treatment selection tool that can be used in Virginia maintenance districts.

In the development of the treatment performance models, it was found that THMACO and chip seal had the highest expected performance of the four treatments. Slurry seal and microsurfacing treatments have the potential to provide benefit to pavement performance; however, if these treatments are applied in suboptimal conditions, their benefit is negligible.

In the development and execution of the district level selection tool, it was found that the treatments recommended for application were mainly THMACO and chip seal. It is believed that the high expected performance of THMACO and chip seal as well as the low expected performance of slurry seal and microsurfacing as shown in the deterioration models created a bias in favor of selection of THMACO and chip seal.

Recommendations to Improve Models

Recommendations that can improve the models used are to:

- Perform a review of existing pavement data so that pavement age and condition data reflect the actual conditions of the pavement.
- Continue to monitor pavement performance over time and update the PMS so that deterioration models can be updated and improved.
- Ensure that all pavement treatments are recorded so that increases in pavement condition correspond to a treatment being applied to that pavement.

Implementation Recommendations

The implementation recommendations are to:

- Avoid a “worst first” approach. If possible, preventive maintenance should be used in tandem with major rehabilitation to establish a balance: fix the roads that are in dire need of repair, while preventing good roads from deteriorating to that point.
- Use the results of unconstrained analysis as a starting point for treatment selection. This analysis provides maintenance category recommendations so that network condition can be improved over time.
- Use a consistent approach for determining treatment feasibility within each district.
- Obtain cost data specific to each district, so that the most accurate cost and cost-effectiveness estimations can be computed.

Based on the results of this study, it is recommended that this district level treatment selection tool is implemented in the maintenance districts in Virginia. This tool has the capability of providing consistent recommendations (within the limitations of the system) for preventive maintenance applications across the state, and potentially improving network condition by promoting the use of the right treatment on the right pavement at the right time.
ACKNOWLEDGMENTS

The research team would like to thank the VDOT central office for access to the PMS for this study as well as pavement managers and district maintenance staff at the Salem, Richmond, and NOVA districts.

REFERENCES


