USE OF VDOT’S PAVEMENT MANAGEMENT SYSTEM TO PROACTIVELY PLAN AND MONITOR PAVEMENT MAINTENANCE AND REHABILITATION ACTIVITIES TO MEET THE AGENCY’S PERFORMANCE TARGET

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ABSTRACT
The Virginia Department of Transportation (VDOT) has an established Pavement Management Program that includes data collection, needs assessment, performance targets, and performance-based budgeting. As a part of data collection and needs assessment, an annual survey of pavement condition is used to estimate the current and project the future pavement maintenance and rehabilitation needs. Pavement condition targets are established, and are used to monitor and assess the effectiveness of maintenance and rehabilitation activities, as well as prioritize the use of limited funds. A performance-based budgeting process establishes budget allocations based on scenarios showing the expected system performance that can be achieved at different levels of investment.

To achieve these goals of the Program, VDOT has relied on the Pavement Management System (PMS) to store, report, and analyze the annual pavement condition data, estimate pavement maintenance and rehabilitation needs through multi-constraint optimization and predict future performance. To meet the established performance targets, various treatment types are recommended by the PMS for the entire pavement network. The current approach has focused on using the PMS to provide information for needs assessment, budgeting, and program development. However, there is a need to provide traceability between the treatments selected by the PMS through optimization, which provides the basis for budgeting and the work actually planned and performed in the field. A process is established that helps track the planned projects and assess the impacts of changes in budget throughout the year allowing pavement professionals to take proactive steps to make the most effective decisions.

INTRODUCTION
Maintenance of a pavement network requires the execution of well-planned Maintenance and Rehabilitation (M&R) activities. While typically the pavement management system provides the recommended M&R activities for various pavement sections constituting the network, the actual application in the field requires a more detailed project level analysis. Detailed project level analysis in general considers more factors that drive the treatment decision for a section that is best suited for that section. While there was found to be a good relationship between the activities recommended from network level to that actually applied for the sections, some project level analysis could lead to a different treatment recommendation.

Though the application of the best treatment for a section is imperative, it is also important to choose a set of M&R treatments for the entire network supported by project level analysis that could best meet the requirements derived from network level analysis for optimal maintenance. To manage the network of approximately 57,000 centerline miles of pavement network maintained by the Virginia Department of Transportation, it is recognized that there needs to be a performance monitoring process implemented in order to meet the network performance targets obtained as optimal solutions from PMS. It was also recognized that it is necessary to have this monitoring conducted at regular and frequent intervals to assure any deviations from the optimal solution are immediately identified and ample opportunity is provided for course correction. Overall, the monitoring process provides the type and location of M&R recommendations for the network as more information becomes available at various stages in the development and execution of planned M&R activities.

This paper provides details of the performance monitoring process developed and adopted over two years ago. Starting with the condition data collected two years ago and the paving projects to be executed that year, the steps used in developing the M&R projects for the
recently concluded paving season and the role of the performance monitoring process in aiding that are detailed. Also, the results obtained for the current monitoring year are presented.

BACKGROUND

The Virginia Department of Transportation tracks the Critical Condition Index (CCI) on its pavements. The CCI is based on the lower of two calculated ratings: the Load-related Distress Rating (LDR) and the Non-load-related Distress Rating (NDR). The LDR and NDR are both calculated based on the PCI procedure developed by the Army Corps of Engineers. As their names suggest, the LDR considers only load-related distresses, while the NDR considers only non-load-related distresses. CCI ratings range from a rating of 0 (worst condition) to 100 (best condition). A “sufficient” pavement has a CCI rating greater than or equal to 60.

VDOT has a pavement program strategy identified for interstate, primary, and secondary systems.

• Interstate pavements are to maintain a sufficiency greater than or equal to 82% with no management section rated with a CCI less than 30.
• Primary pavements are to maintain a sufficiency greater than or equal to 82%.
• Secondary pavements are to maintain a sufficiency greater than or equal to 65%.

These performance targets were set based on the reviews of targets by other agencies, the current condition of the VDOT pavement network, and realistic targets that could be achieved with the expected allocations for maintenance and rehabilitation.

PERFORMANCE MEASURES USED BY OTHER AGENCIES

Performance measures have been adopted by many state and local transportation agencies as well as the Federal Highway Administration. Some performance measures and targets are discussed in the following section.

Federal Highway Administration (FHWA) [1]
The Federal Highway administration tracks the percent of vehicle miles traveled (VMT) on pavements with “good”, “acceptable”, or “not acceptable” ride quality. Ride quality is measured using the International Roughness Index (IRI) and this value is computed in inches per mile. A “good” pavement has an IRI value less than 95, and “acceptable” pavement has an IRI value greater than or equal to 95 but less than or equal to 170, and a “not acceptable” pavement has an IRI value greater than 170.

As stated in the report, the nation’s current condition is that 60% of pavements are in “good” condition, and 93% of pavements are in “acceptable” condition.

Texas Department of Transportation (TxDOT) [2]
The Texas Department of Transportation tracks the Pavement Management Information System (PMIS) Condition Score on its pavements. The PMIS Condition Score combines pavement surface distresses such as rutting, cracking, potholes, punchouts, and patches, as well as ride quality into a single index which ranges from 1 (worst condition) to 100 (best condition). A “good” pavement has a PMIS Condition Score greater than or equal to 70.

As stated in the report, the state’s current condition is that 86.69% of pavements are in “good” or better condition in 2006. The state has a performance target of 90% of pavements in “good” or better condition within the next 10 years.
North Carolina Department of Transportation (NCDOT) [3]
The North Carolina Department of Transportation tracks the Pavement Condition Rating (PCR) on its pavements. PCR ratings range from a rating of 0 (worst condition) to 100 (best condition). A “good” pavement has a PCR that is greater than or equal to 80.

As stated in the report, the state’s current condition is an average of 81.4 on the Interstate System, 63.3 on the Primary System, and 69.36 on the Secondary System. The state has performance targets of 85 on the Interstate System, 80 on the Primary System, and 75 on the Secondary System.

Washington State Department of Transportation (WSDOT) [4]
The Washington State Department of Transportation tracks the Pavement Condition Index (PCI) on its pavements. The PCI is the lowest category of three indices: Pavement Structural Condition (PSC), International Roughness Index (IRI) (in inches/mile), and Rutting (in inches). The categories used for PSC, IRI, and rutting are outlined in Table 1.

<table>
<thead>
<tr>
<th>PSC</th>
<th>IRI</th>
<th>Rutting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Good</td>
<td>100-80</td>
<td>&lt;95</td>
</tr>
<tr>
<td>Good</td>
<td>80-60</td>
<td>95-170</td>
</tr>
<tr>
<td>Fair</td>
<td>60-40</td>
<td>170-220</td>
</tr>
<tr>
<td>Poor</td>
<td>40-20</td>
<td>220-320</td>
</tr>
<tr>
<td>Very Poor</td>
<td>0-20</td>
<td>&gt;320</td>
</tr>
</tbody>
</table>

As stated in the report, the state’s condition in 2005 is 93% of pavements are in “fair” or better condition. The state has performance targets of 90% of pavements in “fair” or better condition.

Minnesota Department of Transportation (MnDOT) [5]
The Minnesota Department of Transportation tracks the Ride Quality Index (RQI) on its pavements. The RQI represents the rating that a typical road user would give to the pavement’s smoothness as felt while driving his/her vehicle. The RQI categories are outlined in Table 2.

<table>
<thead>
<tr>
<th>RQI</th>
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<tbody>
<tr>
<td>Very Good</td>
</tr>
<tr>
<td>Good</td>
</tr>
<tr>
<td>Fair</td>
</tr>
<tr>
<td>Poor</td>
</tr>
<tr>
<td>Very Poor</td>
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As stated in the report, the state’s condition in 2006 is 68.9% of pavements having “good” or “very good” RQI and 2.3% of pavements having “poor” or “very poor” RQI for Principal Arterials, and 61.1% of pavements having “good” or “very good” RQI and 5.2% of pavements having “poor” or “very poor” RQI for Non-Principal Arterials. The state has performance targets of 70% or more of pavements having “good” or “very good” RQI and 2% or fewer of pavements having “poor” or “very poor” RQI for Principal Arterials, and 65% or more of pavements having
“good” or “very good” RQI and 3% or less of pavements having “poor” or “very poor” RQI for Non-Principal Arterials.

**METHODOLOGY**

As a way of managing the pavement network at desired performance levels, a performance monitoring process is established. This process uses the latest available condition data and budget allocations for each maintenance district to establish performance targets based on optimization analysis in PMS. To achieve these performance targets, further guidance is provided in the form of target lane miles of M&R treatments that are categorized into preventive, corrective, restorative, and major rehabilitation/reconstruction. Such targets help in the choice of appropriate treatment types for the network. Detailed performance monitoring process has been implemented to ensure that reasonable baseline treatment targets are established each year. Based on available budget allocations, the adherence to these targets is tracked from schedule development through work completion. The focus will be on how the Pavement Management System (PMS) is used to:

i. establish baseline performance and paving targets,
ii. track planned paving projects through completion of work,
iii. program planned projects into performance prediction tools to ensure adequacy of planned paving to meet baseline targets and,
iv. validate project level treatment selection through the use of detailed distress, traffic, surface age, and structural condition information.

The monitoring process starts with the use of the latest available condition data which is collected on an annual basis on 100% of interstate and primary network, and about 20% of the secondary network. For each of the nine maintenance districts of VDOT, performance targets are established separately for the interstate, primary, and secondary networks. The establishment of initial targets is based on the optimization analysis in PMS using the planned budget for the paving year. These initial targets are compared with the planned M&R activities at that time that are still in the early stages of development. As shown in Fig. 1, the initial list of treatment selections are revised by the addition of more projects or modification of existing projects.

Districts plan the next year’s paving using a tool developed in-house where they can specify location detail, treatment category, items and quantities, and they can effectively estimate project cost. When initial schedule development is complete, these planned projects are loaded in the PMS as pipeline projects and performance targets are established using the PMS optimization analysis capabilities. The objective is to maximize benefit while satisfying budgetary as well as specified performance constraints. Subsequently, this process is repeated as information about firmed-up budget allocations becomes available. Revision of the planned M&R activities continues at various times of the year as efforts are made to meet the performance targets. Execution of the paving or M&R work is accomplished through the contracts that are awarded at the end of every year for the next paving season.
FIGURE 1 Steps in the Project Development and Performance Monitoring.

The timeline for performance monitoring and revision/addition of projects is shown in Figure 2. In February, while projects are being planned for the next paving season, the initial performance targets and initial paving targets are established. This is also the time of the year when the targets established in the previous year could be compared with projects awarded for the current paving season. Such comparisons not only show how closely the targets and actual
work awarded align with each other but also provide an opportunity to fine-tune the analysis process.

![Figure 2 Timeline of PMS Updates and Performance Monitoring.]

**FIGURE 2  Timeline of PMS Updates and Performance Monitoring.**

**Performance Targets**

With PMS paving needs analysis as an input, the annual paving budget is published for each district and system in April of every year, and each of the nine maintenance districts has to plan its paving based on this allocation. During May the current year’s condition data becomes available in PMS. To assist in the planning phase, the Central Office Maintenance Division prepares targets for the districts to provide guidance in terms of how many lane miles they should schedule for each category of maintenance: Preventive Maintenance (PM), Corrective Maintenance (CM), Restorative Maintenance (RM), and Rehabilitation/Reconstruction (RC). Based on the allocations available, the performance targets that could be achieved by the maintenance districts are determined. If the districts already meet or exceed the desired performance targets, then the targets for those districts would be the best levels that could be achieved above the desired target. On the other hand, if the districts are below the desired target levels, then the targets for those districts would be to get those districts as close as possible to the desired target levels, or exceed those if possible. In both the cases, the performance target levels in terms of percent of network in sufficient condition as well as the number of lane miles of M&R treatment types to be provided under various categories are provided to the districts.

An extract from a performance monitoring report which shows the performance targets for interstate and primary pavements is shown in Figure 3. This upper portion of the chart shows the network condition from the data collected for the 2011 collection season which occurs before the start of the paving season in 2011. Employing this data, the prediction of the network performance in 2012 is presented based on the paving work for 2011 along with the network deterioration over a period of one year as determined from the prediction models. Subsequently, based on the allocations for the 2012 paving season that would support the 2012 paving work, the network target performance is established for 2013 by optimization analysis in PMS.

Toward meeting these targets, districts plan the M&R work and this is used to determine whether the targets can be met, and the results are published as the predicted condition in 2013. The lower portion of the Fig. 3 shows the difference between the target performance level and the performance level that could be achieved based on planned work. In the case of interstate
network, it is seen the target is exceeded by 1.3% but for the primary network the performance falls short by 0.6%. Such charts provide an easily understood guidance to plan for meeting the targets.

Given initial pavement conditions, expected deterioration and planned paving, Hampton Roads District is predicted to achieve its 2013 performance target of 83.0% of Interstate network in Sufficient Condition and is not predicted to achieve its 2013 performance target of 79.0% of Primary network in Sufficient Condition.

FIGURE 3 Target and Expected Performance for a Maintenance District.

An additional extract from a performance monitoring report which shows the targeted and planned lane miles of treatments under various categories for interstate and primary pavements is shown in Fig. 4. Here the upper portion of the figure shows the lane miles of various treatments awarded for execution in 2011. Also shown are the planned lane miles of work and the target lane miles for 2012. The difference between the planned and target lane miles are shown in the lower portion of the figure. It is seen that for the interstate, the planned lane miles under the corrective maintenance category exceeds the target by 8 lane miles. The planned rehabilitation/reconstruction work matches the target lane miles. However, the planned lane miles fall short of the targets under preventive and restorative maintenance categories by 3 and 2 lane miles, respectively.
FIGURE 4 Target and Planned Lane Miles of Treatment for a Maintenance District.

Final Targets
In July, the finalized unit costs of various items constituting the pavement treatments under various categories are available. Therefore, all the expected inputs that go into treatment determination for the network are available in the finalized form. These include the pavement condition data for the year, the budget allocations for the upcoming paving season, and the unit costs of various items of treatments. Consequently, the final performance and paving targets are determined as no more changes are expected to the inputs. Any changes occurring beyond this time period are expected to be rare. The planned M&R treatments are tracked at every stage of target determination.

Tracking of Projects
After the final targets are set in July, the planned M&R projects are tracked on a more frequent basis. Based on previous planning, the districts are finalizing the treatment projects from August through November. The process of frequent tracking of projects at this stage allows for course corrections in the choice of projects to reach the established targets. By November, the final project lists are established and the tracking process provides one more chance to make changes before the projects are advertised.
RESULTS

The results of performance monitoring with the data from 2012 are shown here. Initial baseline targets were published in May 2013. These targets were the initial step that allowed the districts to start preliminary planning for paving in the following calendar year. These targets were developed using PMS optimization analysis, which used 2012 condition data, predicted pavement deterioration using the deterioration models within the system, and determined proposed paving based on the allocations published in April 2013. At this point, the districts were not expected to have planned work ready, since this report is intended to be a guideline for future planning.

In August 2013, the targets were re-run with new condition data that was made available for 2013. There was also an influx in funding for reconstruction projects on the interstate, which resulted in a drastic increase in RC lane miles for the August target. Districts planned work in August 2013 based on the initial targets published in May, plus extra work based on the reconstruction funding that was made available.

In November 2013, the districts received further supplemental funding and the targets were again rerun. The districts responded to the changes in targets and funding by adjusting their planned lane miles accordingly.

In January and February 2014, both the targets and the work planned by the districts remained stable. At this point, the districts finalized their planned paving for the 2014 construction season.

These trends in target lane miles and planned lane miles are shown in Figure 5 for Interstate pavements and Figure 6 for Primary pavements.

The expected percent sufficient values based on target lane miles and planned lane miles were also obtained for each milestone report. These values changed based on the changes in target lane miles and work planned by the districts, and these trends are shown in Figure 7.

As a final step of the performance monitoring process, project level treatment selections are validated through the use of detailed distress, traffic, surface age, and structural condition information.
FIGURE 5 Interstate Target and Planned Lane miles for (a) PM, (b) CM, (c) RM, (d) RC.
FIGURE 6 Primary Target and Planned Lane miles for (a) PM, (b) CM, (c) RM, (d) RC.
FIGURE 7  Percent Sufficient for (a) Interstate Pavements and (b) Primary Pavements.

CONCLUSIONS

A performance monitoring process is presented here that aids in the development of an M&R strategy for the pavement network. Depending on the time of the year at which the network treatments plans begin, expected performance reports are developed that take into account the treatment plans developed until that point of time, and provides guidance for further development of the plans for the paving season under consideration. The reporting intervals vary from as long as a quarter year in the initial stages, to once a month at the later stages of treatment.
plan development. A sample report is presented that shows the details of the monitoring process, and provides an indication of the needed changes.

Results from the monitoring process presented here show that the M&R plans progressively improve toward meeting the defined network goals. Establishment of a performance monitoring process has helped in insuring that the network level objectives are met with respect to the maintenance of the roadway network. For this purpose, a well-defined dynamic analysis process, monitoring procedure of the choice of treatments, consistent reporting procedures, and appropriate time intervals for monitoring have been established.

REFERENCES