Pavement Management Systems Peer Exchange Program Report

(Sharing the Experiences of the California, Minnesota, New York, and Utah Departments of Transportation)

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U.S. Department of Transportation
Federal Highway Administration

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EXECUTIVE SUMMARY

The funding situation for transportation agencies is not expected to improve in the next several years, forcing agencies to clearly identify investment priorities. As a result, many transportation agencies have instated or are considering asset management as a strategic approach for managing their highway infrastructure. Some of these agencies are taking actions that are directly related to asset management principles, such as shifting funds away from large expansion projects and focusing available funding on the preservation of existing assets. The implementation of cost-effective strategies, such as the use of preventive maintenance treatments on roads and highways in good condition, are becoming increasingly important to make the best use of the available funds by slowing down the rate of pavement deterioration and postponing the need for more costly improvements.

The key to successfully navigating this type of economic climate is the availability of reliable asset condition information and economic analysis tools that can quickly simulate the consequences associated with different investment strategies. A number of state highway agencies rely on their pavement management programs to provide this information to support the agency's decisions about pavement-related investments.

In 2008, the Federal Highway Administration's (FHWA's) Office of Asset Management initiated a Peer Exchange Program to promote the effective use of Pavement Management Systems (PMS) in general and more informed decision making in particular. The first two Peer Exchange meetings allowed representatives from the New York State Department of Transportation (NYSDOT) and the California Department of Transportation (Caltrans) to meet with pavement management practitioners in Minnesota and Utah to learn more about the use of their pavement management program to support investment decisions and to influence project and treatment selection. Through the Peer Exchange meetings, which were held early in February, representatives from the Minnesota Department of Transportation (Mn/DOT) and Utah Department of Transportation (UDOT) presented information explaining how pavement management tools are being used to:

- Provide the information used for long-term planning to address future pavement needs.
- Establish strategic performance targets based on realistic estimates of future funding levels.
- Set investment levels for pavement preservation programs that extend the life of pavements in relatively good condition before more costly rehabilitation is needed.
- Support the project and treatment decision process in the Districts and Regions by providing them with useful information that can substantially influence their work program.
- Conduct engineering and economic analyses that evaluate the cost-effectiveness of treatment options in support of the agency's asset management practices.

This report summarizes the use of pavement management tools to support agency decisions in UDOT and Mn/DOT, provides tips for procuring new pavement management software, and identifies institutional issues that must be addressed to make the most of a pavement management program. It closes with a summary of the key factors influencing the successful

pavement management practices in UDOT and Mn/DOT, which include the following considerations.

- Consistency in the pavement management personnel operating the system.
- The use of quality data so the pavement management program provides reliable recommendations.
- A strong relationship with the software providers so any issues that arise can be addressed immediately.
- A commitment to pavement management concepts throughout the organization.
- The involvement of pavement management stakeholders in decisions regarding changes to the analysis models.
- The use of software tools that are flexible enough to adapt to the changing environment in which they must operate.

The strong pavement management programs in each of the host agencies have resulted in improvements in the quality of information used to make investment decisions. Both Mn/DOT and UDOT have been able to use their pavement management information to effectively revise investment priorities during periods in which competition for available funding has increased. As a result, both agencies have established strategic plans that increase the emphasis on system preservation and align their project and treatment selection process in accordance with those plans.

As the Peer Exchange meetings demonstrated, strong pavement management programs can benefit transportation agencies tremendously. The information provided during the meetings, which is documented in this report, provides valuable insight into the practices of the participating transportation agencies and the factors that have contributed most to their success. The information is provided so that other agencies can benefit from the experience and develop strategies that enhance their own pavement management practices.

INTRODUCTION

In a 2006 survey of the Federal Highway Administration (FHWA) Division Office personnel conducted by the FHWA's Office of Asset Management, 15 respondents indicated they were either in the process of upgrading or replacing their pavement management software or would be doing so within the next several years. The same survey found that a significant number of agencies were not fully utilizing their pavement management information to influence agency decisions. In light of today's increased competition for available funding and less institutional knowledge due to staffing cutbacks and retirements, the importance of effective pavement management practices can not be underestimated. Therefore, in 2008 the FHWA initiated a Pavement Management Peer Exchange Program to share information and experience on the effective use of pavement management practices among state highway agencies. This report documents the first two Peer Exchange meetings, which provided an opportunity for representatives from the New York State Department of Transportation (NYSDOT), the California Department of Transportation (Caltrans), and the FHWA to attend presentations conducted by the Minnesota Department of Transportation (Mn/DOT) and the Utah Department of Transportation (UDOT). Experts from various disciplines within each agency were invited to participate in the meetings since the success of the pavement management program relies on their full support. The meetings were held February 4-5, 2008 in Maplewood, Minnesota and February 7-8, 2008 in Salt Lake City, Utah. The participants in the Peer Exchange are listed in table 1.

Table 1. Participants in the Peer Exchange Program

New York DOT	**Minnesota DOT**
Tom Weiner, Planning Engineer	Dave Janisch, Pavement Management Engineer
Bob Semrau, Pavement Management Engineer	Keith Shannon, Director, Office of Materials
Joe McClean, Office of Policy & Strategy	Peggy Reichert, Director, Statewide Planning
Rick Bennett, Chief, Pavement Management	Curt Turgeon, Pavement Engineer
Caltrans	**Utah DOT**
Susan Massey, Chief, Office of Roadway Rehabilitation	Tim Rose, Director for Asset Management
Peter Vacura, Pavement Management Project Manager	Peter Jager, Engineer for Planning Statistics
Rick Guevel, Division of Transportation Planning	Gary Kuhl, Pavement Management Engineer
Eugene Mallette, State Pavement Program Manager	Steve Poulsen, Asset Analysis Engineer
FHWA	Russ Scovil, Field Inventory Engineer
Tim LaCoss, NY Division	Robert Pelly, Statewide Transportation Improvement Program Coordinator
Steve Healow, CA Division	Lloyd Neeley, Deputy Engineer for Maintenance
Nastaran Saadatmand, Office of Asset Management	Austin Baysiner, Pavement Modeling Engineer
Bill Lohr, MN Division	Ahmad Jaber, Director of Systems Planning and Programming
Doug Atkin, UT Division	**Recorder**
	Katie Zimmerman, Applied Pavement Technology, Inc.

Objective

The Pavement Management Peer Exchange Program provides an opportunity for practitioners to share information about pavement management practices. It was designed to achieve two primary objectives. First, it provided a forum for the exchange of ideas and practices to take place among the participants. Although an agenda was provided for the meetings, no pavement management topic was considered off limits. The second objective was to share the lessons learned with other practitioners who were not able to attend the meetings. This report, and the

technology transfer activities that will follow its production, were developed to meet this second objective.

Peer Exchange Approach

The two Peer Exchange sessions were each designed as 2-day meetings, with a series of presentations provided by the host agency. Each host agency provided an overview of its pavement management program, including detailed discussions about data collection and analysis activities. Additionally, the host agencies were asked to address the use of pavement management information to support decisions at the strategic, network, and project levels. Topics included the following:

1. Supporting the project selection process using pavement management information.
2. Using pavement management information to support planning activities, such as the development of the Long Range Transportation Plan (LRTP) and the Statewide Transportation Improvement Program (STIP).
3. Implementing strategies for communicating pavement management information throughout the agency.
4. Establishing and maintaining links with Maintenance and Operations.
5. Using pavement management information to conduct engineering and economic analyses.
6. Establishing feedback loops with actual performance data to improve pavement management models.

Each session ended with an open discussion in which the participants were invited to ask questions of the others. During this time, the participating agencies were able to ask specific questions about topics ranging from software procurement to system design. The open format for this portion of the meeting significantly contributed to the overall success of the Peer Exchange Program, since it provided an opportunity for the participating agencies to better sort out vendor claims from realistic accomplishments. In the end, the questions posed by the participating agencies were focused on determining the types of support a pavement management program could realistically provide and the best ways to meet that level of accomplishment. This report summarizes their findings.

Participating Agencies

The Peer Exchange Program is sponsored by the FHWA's Office of Asset Management. Mn/DOT and UDOT were selected as the host agencies primarily due to their strong reputation in the industry and the maturity of their pavement management practices. However, other factors, such as the diversity in traffic levels, the differences in pavement management software, and the commitment to pavement preservation, also played a role in their selection. Background information on each of the host agencies is provided. NYSDOT and Caltrans were chosen to participate in the Peer Exchange Program as other participating agencies based on their upcoming activities, which will significantly enhance their existing pavement management programs. Information on these other participants is also included.

Minnesota DOT

Historically, pavement management decisions at Mn/DOT have primarily resided in the Districts with support provided by the central office. However, in recent years there has been more of an

emphasis on the information provided by pavement management personnel in the central office, which has both raised the profile of pavement management in the agency and shifted the types of support provided by central office staff to the field offices. The importance of pavement management tools has increased in the wake of the 2007 I-35W bridge collapse, with the State's Office of the Legislative Auditor conducting a program review of Mn/DOT. The Mn/DOT Commissioner, who also serves as the Lieutenant Governor for the State, regularly receives updates and status reports from pavement management.

Mn/DOT is responsible for the maintenance of more than 30,000 lane miles on the state system. Pavement distress and roughness data have been collected on the state system since the late 1960s, and the DOT currently owns two data collection vans that are used to collect the information for both the State and County systems. To store its roadway information, Mn/DOT initially developed the Transportation Information System (TIS) as a mainframe database for use by the entire agency. In 1987, Mn/DOT implemented the HPMA pavement management software developed by Stantec. The software, which uses TIS as one of the primary sources of storing roadway inventory data, is used to analyze performance trends and to optimize the use of funding for long-range planning and budgeting activities. The Pavement Management Unit is located within the Office of Materials of the Engineering Services Division. In addition to the Pavement Management Engineer, there are four raters, a statistician, a technician, an engineering specialist to supervise the raters and process the data to/from the TIS, and a Preventive Maintenance Engineer available to assist with the data collection, analysis, and reporting of pavement management information.

Utah DOT

UDOT was an early leader in promoting pavement management concepts by publishing the study *Good Roads Cost Less* in 1977 (UDOT-MR-77-8). While the tools used to manage its pavements have changed with time, UDOT continues to emphasize sound pavement management principles, including the use of preventive maintenance strategies for pavement preservation. UDOT currently uses the dTIMS CT software developed by Deighton and Associates to assist in managing 5825 centerline miles of interstate, arterial, and collector routes. Pavement management is housed with the Division of Asset Management within Systems Planning and Programming. Primary responsibilities include collecting and analyzing pavement condition data, forecasting future pavement conditions and needs, recommending treatment strategies to the Region offices, and recommending funding needs to upper level decision makers. UDOT is currently developing an asset management model, using dTIMS, to evaluate investment trade-offs for pavements, bridges, and safety needs. The Division is managed by a Director and staffed with two engineers and two data collection personnel.

In addition to the data collected by the central office personnel, Region Pavement Management Engineers are responsible for collecting pavement distress information. However, UDOT recently advertised for a contractor to automate the distress data collection activities, so the Asset Management Division is planning for the modifications to the existing procedures anticipated with this change.

Other Participating Agencies

Caltrans and the NYSDOT were selected as participating agencies by the FHWA since both agencies are in the process of acquiring new pavement management software. Caltrans is initiating wholesale changes to its pavement management practices. In addition to implementing new software, the agency is revising its data collection procedures to be more objective and plans

to collect network-level structural information to support the analysis. The University of California at Berkeley is expected to be heavily involved in developing the analysis models and assisting Caltrans with the implementation and operation of its new software.

NYSDOT has utilized internally-developed software for its pavement management activities for many years. However, the Department is initiating the process of securing new pavement management software that provides both increased flexibility and improved optimization and prioritization capabilities. NYSDOT currently conducts its own data collection activities supplemented with contracted services, and plans to continue using these procedures after the new software is installed.

The timing of the Peer Exchange Program meetings provided a unique opportunity for each participating agency to move forward with their implementation plans with more confidence and with a better understanding of the possible implications of various implementation options they are considering.

Representatives from the FHWA's New York, California, Minnesota, and Utah Division Offices also participated in the meetings.

Peer Exchange Focus Areas

The topics covered during each of the two Peer Exchange meetings were presented earlier in this report. The range of topics was intended to illustrate the use of pavement management information to establish pavement preservation priorities and to support each agency's decision making process. In addition to presenting the traditional uses of pavement management information to support the identification and prioritization of pavement preservation needs, the host agencies were asked to spend some time addressing their expanded uses of pavement management information. This allowed the host agencies to illustrate how pavement management information is linked to long-term planning (in Minnesota), how pavement preservation programs are integrated with pavement management (in both Minnesota and Utah), and how pavement management is being formally aligned with an agency's asset management program (in Utah). Further information on these broadened uses of pavement management information is provided later in the report.

Special Interests of Participating Agencies

In addition to the formal topics discussed during the Peer Exchange sessions, the representatives from the NYSDOT and Caltrans provided additional topics for the host agencies to address. These additional topics were tailored to the specific needs of the participating agencies and focused primarily on the issues facing each agency at the time of the Peer Exchange Program meetings. For instance, the questions posed by the NYSDOT focused primarily on the procurement of software and the operation of the software within each host agency. These participants were interested in the procurement and implementation processes themselves, the resources needed to operate the software once it was in place, the amount of training and technical support provided by the vendors, and the use of the software in field offices.

Since Caltrans has already selected its pavement management software, their questions focused more on the use of pavement management to support funding requests and funding allocations. Specific questions were asked about the process for reporting funding needs to decision makers, the rigor of the "what if" scenarios used to defend funding requests, and the number of funding

sources considered in the analysis by each agency. Additionally, since Caltrans is in the process of developing new pavement condition survey procedures, they asked the host states several questions about their data collection and quality control/quality assurance (QC/QA) procedures.

Using the Report as a Guide to a Successful and Fully Utilized Pavement Management Program

This report was developed to transfer the information obtained during the Peer Exchange to practitioners in agencies that were not able to attend the meetings. Its contents can be used to learn more about the factors that have contributed to the success of the pavement management programs in Minnesota and Utah by summarizing their pavement management practices in the following areas:

- Developing procedures to obtain reliable pavement condition information (see the section on *Data Collection Activities* beginning on page 7).
- Strengthening the links with Maintenance and Operations (see the section on *Links to Maintenance and Operations* beginning on page 9).
- Implementing pavement management tools that support agency planning and programming decisions (see the section on *Links to Planning and Programming Activities* beginning on page 11).
- Using pavement management to support project and treatment selection decisions within Regional or District offices (see the section on *Influence of Pavement Management on Project and Treatment Selection* beginning on page 13).
- Using pavement management to support engineering and economic analyses (see the section on *Engineering and Economic Analysis* beginning on page 19).
- Linking pavement management to an agency's asset management practices (see the section on *Links to Asset Management* beginning on page 21).
- Using pavement management data to support other data needs (see the section on the *Availability of Data to Support Other Needs* beginning on page 21).
- Planning for the on-going support of a pavement management program (see the section on *Support of Upper Management* beginning on page 23, the section on *Staffing and Other Resources* beginning on page 23, and the section on *Future Activities and Directions* beginning on page 26).
- Finding keys to a successful pavement management implementation (see the section on *Software Selection and Procurement* beginning on page 24, the section on *Institutional or Implementation Issues* beginning on page 26, the section on *Key Success Factors* beginning on page 28, and the section on *Benefits Realized* beginning on page 31).

The report concludes with a summary of the benefits associated with the Peer Exchange and the FHWA's plans for future sessions.

FINDINGS AND OBSERVATIONS

Although the topics raised during the Peer Exchange were specific to these participants, they are equally relevant to many other state highway agencies with initiatives underway to enhance their existing pavement management program. Whether an agency is looking to implement new pavement management software or improve the reliability of its data collection procedures, or whether an agency is looking to increase the use of pavement management information in its decision process or incorporate pavement preventive maintenance treatments into its pavement management software, the findings from the Peer Exchange provide an opportunity to learn more about how these issues are being addressed successfully by Mn/DOT and UDOT. This section of the report summarizes the findings and observations in a number of areas that were raised during the Peer Exchange.

Data Collection Activities

Mn/DOT

Mn/DOT has been collecting pavement distress and roughness data for approximately 40 years. The condition data are collected and analyzed each year; the results are loaded into TIS and extracted into the HPMA data tables for use in the pavement management analysis. The availability of the data in TIS assures easy access to the condition data for individuals in both the central office and the regional offices.

Pavement condition information is collected using one of two state-owned Pathway Services Digital Inspection Vehicles. The equipment is used to collect roughness, rutting, cracking, and faulting as well as digital images of the pavement surface. Table 2 summarizes the data collection protocols used by Mn/DOT. The equipment is replaced about every five years.

Table 2. Mn/DOT pavement condition data collection procedures.

Roughness & Rutting	• Collected annually on all trunk highways • Collected annually on ¼ of the County State Aid system • Roads driven in both directions • Data stored on a mile-by-mile basis • Outer lane is measured in the left and right wheel paths
Cracking & Faulting	• Collected on approximately 60% of the system annually • Collected annually on ¼ of the County State Aid system • First 500 feet of each mile is surveyed (10%) • Only one direction is surveyed on 2-lane roads
Digital Images	• Collected annually on all trunk highways • Collected annually on ¼ of the County State Aid system

Pavement condition data is used to calculate three condition indexes: a surface rating (SR) that ranges from 0 to 4 based on the amount of cracking, rutting, faulting, and other distress present; a ride quality index (RQI) that converts an International Roughness Index (IRI) to a 0 to 5 scale, and a Pavement Quality Index (PQI) that is calculated from the SR and RQI. MnDOT calculates remaining service life (RSL) values by estimating the number of years until the RQI reaches a value of 2.5, which signifies the point at which major rehabilitation is required. Project and treatment selection are heavily weighted in terms of the RQI, and performance targets for this

index have been established. The current RQI targets to achieve by the year 2014 are listed in table 3.

Table 3. Mn/DOT RQI targets for 2014.

Condition Category	Principal Arterials	Non-Principal Arterials
Very Good (4.1-5.0) Good (3.1-4.0)	70% or more	65% or more
Poor (1.1-2.0) Very Poor (0.0-1.0)	2% or less	3% or less

Condition data are reported in a number of different formats. For example, a trifold fact sheet is produced annually showing the number of miles of each type of pavement and the average condition for the network by various groupings. An Executive Summary is produced for District Engineers to summarize their network conditions and to indicate whether or not their performance targets have been met. Map displays are also produced and provided to the Districts.

Mn/DOT is fairly unique in that the State provides data collection to counties on a contract basis. The counties are charged a flat rate of $37/mile to collect condition information on their road network. At the county's request, Mn/DOT will collect the same condition information collected on the state system for the county highways and present the information in a spreadsheet. The Division of State Aid for Local Government pays for the collection of the county data on the County State Aid Highway (CSAH) system. Mn/DOT contracts directly with the counties for testing their non-CSAH routes or when they want additional testing in a year when testing the CSAH system is not scheduled.

UDOT

At the present time, pavement condition data for the state highway system is collected by individuals from both the central office and the Regions. Asset Management staff are responsible for collecting ride and rutting information on hot-mix asphalt (HMA) pavements and ride and faulting on portland cement concrete (PCC) pavement. This information is collected annually using an International Cybernetics Corporation (ICC) van, with one lane in each direction surveyed on interstate pavements and one lane in one direction on the rest of the state routes. In addition, the Asset Management team is responsible for collecting the photo log and for conducting any structural or skid testing that needs to be done at specific locations. Approximately 1800 miles of structural testing is conducted each year using a Jils falling weight deflectometer (FWD), which results in nearly a 3-year cycle for HMA interstate pavements, a 4-year cycle for other HMA routes, and a 5-year interval for PCC pavements. Approximately one test is made in each mile of the road network. Skid resistance is tested each year with half the system tested on odd years and half of even years. In addition to testing state routes, the Department also tests any nearby forest routes and state airports that request skid testing. Currently, the FWD and skid resistance data have limited use in project and treatment selection but eventually they would like to correlate test results to a structural number to help determine the remaining life of a pavement.

In addition to the information collected by the Asset Management section, the Region Pavement Management Engineers collect pavement distress data annually through windshield surveys. Each Region receives $5,000 for collecting the information and any additional costs are funded out of the Region budget. The first tenth mile (500 feet) of each mile in the outer travel lane is inspected. A summary of the type of distress information collected is presented in table 4.

Table 4. UDOT pavement distress data.

HMA-Surfaced Pavements	• Wheel path cracking • Longitudinal & transverse cracking • Skin patches
PCC-Surfaced Pavements	• Corner breaks • Joint spalling • Shattered slabs

Pavement condition information is reported in terms of nine indexes, each on a 0 to 100 scale with 100 representing a road in excellent condition. For asphalt-surfaced pavements, conditions are reported in terms of ride index, rut index, crack index (for environmental cracking), and wheel-path cracking. PCC surface indexes include a ride index, a faulting index, a concrete cracking index (for shattered slabs and corner breaks), and a joint spalling index. An Overall Condition Index (OCI) is calculated for all surfaces by taking the average of the four indexes for each surface type.

In the past, UDOT has had difficulty matching the survey data with field locations, which is one of the reasons they are moving forward with a contract to have a vendor collect pavement condition information using automated equipment. The DOT issued the RFP for data collection services and was in the process of selecting a vendor at the time of the Peer Exchange. UDOT plans to issue a 1-year contract to the vendor with an option for four additional single-year extensions. Under the automated data collection contract, the vendor will collect ride, rutting, faulting, and distress data as well as conduct the photo log. The cost of collecting the data using automated means is expected to be equivalent to the amount being spent by the Department internally, so no additional funding was needed for this change.

The pavement condition information is loaded into the pavement management software and reported to the Regions each fall in a number of different formats. In addition to reporting current and projected conditions, the Pavement Management team provides the Regions with section-by-section treatment recommendations and costs based on the results of an optimization analysis.

Links to Maintenance and Operations

With the increased emphasis on pavement preservation activities in state highway agencies, it is becoming increasingly important for Pavement Management personnel to interface with Maintenance and Operations personnel to coordinate maintenance and rehabilitation activities. In Utah, this interface is strengthened by the fact that the Deputy Engineer for Maintenance formerly served as the Pavement Management Engineer for the State. Therefore, he has a good understanding of the pavement management system and the types of information it uses to make project and treatment recommendations.

UDOT currently utilizes its maintenance management system (MMS) and its Maintenance Management Quality Assurance program (MMQA+) to assist in setting maintenance budgets that are linked to resource requirements and performance targets, although new software is being implemented. MMQA+ uses a sampling approach (a 100 percent sample in most cases), to determine a level of maintenance (LOM) for reporting the performance of UDOT's roadway appurtenances (such as signs, guardrail, and markings) and the effectiveness of maintenance activities (such as snow removal, litter control, and mowing). The results of the surveys are reported in terms of current LOM (as a letter grade) and funding needed to achieve the targeted LOM is estimated. The availability of this type of information allows UDOT to quickly respond to questions about the impact on performance associated with proposed budget cuts. This concept is illustrated in figure 1. As shown in the figure, the budget requirements associated with a high LOM (e.g., A or B) are higher than the cost of maintaining a low LOM (e.g., D or F). Depending on the type and number of assets, the difference in costs associated with different levels of service can vary greatly (represented by the steepness of the cost slope shown in figure 1). Agencies typically try to maintain a higher level of service on high-volume facilities than low-volume facilities and on assets related to safety (such as regulatory signs) over activities associated with aesthetics (such as mowing).

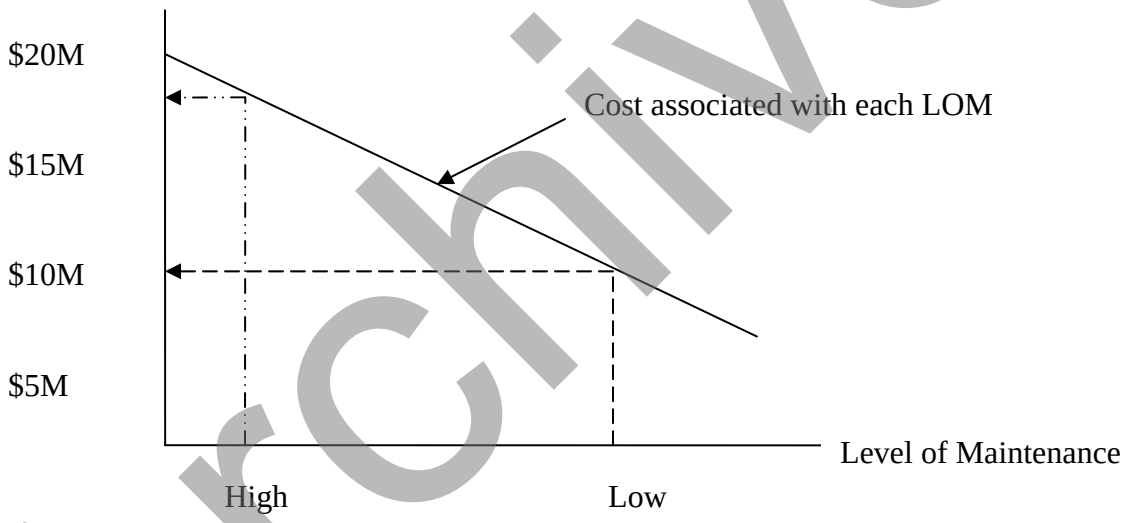

Figure 1. Example of the link between level of maintenance provided and budget needs.

The LOM for pavement activities is linked to the pavement management system through the OCI, which is calculated based on the results of the pavement condition surveys. The OCI will be the pavement performance measure used in the new maintenance management software program selected to replace the MMS and MMQA+ software. The new software, which was developed by AgileAssets and is being referred to at UDOT as the Operations Management System (OMS), has several modules that link LOM to budgeting and resource requirements. UDOT is currently planning to implement AgileAssets' pavements module as a replacement for UDOT's Plan For Every Section database, to further strengthen the link between pavement maintenance and pavement management. The pavements module will store information on inventory and service-level activities so it can be accessed by field personnel or by pavement management for use in performance modeling or treatment selection recommendations. UDOT

envisions having both the maintenance component and the pavements component of the OMS fully operational by the end of 2008.

Mn/DOT does not have as strong a link to maintenance, largely because its work management system reports work activities in units that do not easily link with pavement management sections. However, this is not a huge issue since most preventive maintenance is conducted under contract (rather than with in-house forces) and records of contract maintenance activities are available in the Districts. Mn/DOT does not store its maintenance activities in the pavement management database, but relies on an analysis of pavement deterioration models for each section in the database to identify where maintenance improvements have been made. Mn/DOT's pavement management software has a tool that allows the Pavement Management Engineer to quickly review the historical deterioration trends of each section in the database to determine if any anomalies appear. These anomalies (such as an unexplained increase in condition) are reviewed with District personnel and are typically found to be explained by some type of maintenance activity.

An initiative is currently underway within Mn/DOT to demonstrate the effectiveness of maintenance activities. Using pavement management data, Mn/DOT has determined that smoothness isn't a good measure for documenting these benefits. However, Mn/DOT is considering the use of other performance measures, such as a cracking index, as a way to demonstrate maintenance effectiveness.

A previous initiative involved demonstrating to maintenance personnel that the automated data collection equipment was capable of measuring pavement condition information in sufficient detail to identify where maintenance activities had been performed. The Pavement Management Unit demonstrated its ability to identify concentrated areas of roughness and locations suitable for wedge paving (forcing fine material into depressions with a blade). The results of these activities significantly raised the level of confidence that Maintenance and Operations personnel had in the data collected by pavement management.

Links to Planning and Programming Activities

Mn/DOT

Mn/DOT demonstrated a particularly strong link between pavement management and the Department's long-term planning activities. Minnesota is not unique in the fact that it has several metropolitan areas that are heavily populated and some very rural areas with that are sparsely populated. This demographic has had a significant influence on the Department's investment decisions, including decisions regarding how much to invest in rural roads. Since the District personnel are typically closer to politicians than central office personnel, they have a strong political base to support project and treatment decisions that is not available in the central office. Therefore, the Department is constantly trying to balance its desire for consistent standards and performance targets with the autonomous nature of the eight Districts. The development of a District plan was a deliberate effort to develop more consistency in the Department's planning and programming activities.

At Mn/DOT, pavement management information is an important foundation for the Department's long-term planning activities. In fact, pavement management has been used as a model for long-term planning and the bridge unit has been instructed to develop and implement the same types of forecasting tools currently available in pavement management. An overview

of Mn/DOT's planning and programming process is provided in figure 2. Both the 20-year plans and the 10-year plans (including the first 4 years of the plan, which are updated annually) are based on outputs from the pavement management analysis conducted by the central office.

Investment levels to support the strategic plan are established to achieve specific performance targets established at the policy level for 1) safeguarding what exists, 2) making the transportation network operate better, and 3) making Mn/DOT work better (e.g., through improved efficiencies or better decisions). Within each of these strategic areas, specific policies are established with goals, strategies, and performance targets established for each. For pavement preservation, the performance target is set so 70 percent, or more, of the road network classified as Principal Arterial is in good condition (as shown previously in table 3). This is representative of the condition level that has been maintained over time and, since the public has been reasonably satisfied with this condition level, the Department feels it is a reasonable goal. A "reality check" is applied to ensure that the trunk system maintained by the State does not fall below the condition of the county road network or in neighboring states. This benchmark system has been very useful in preventing decision makers from lowering the performance target.

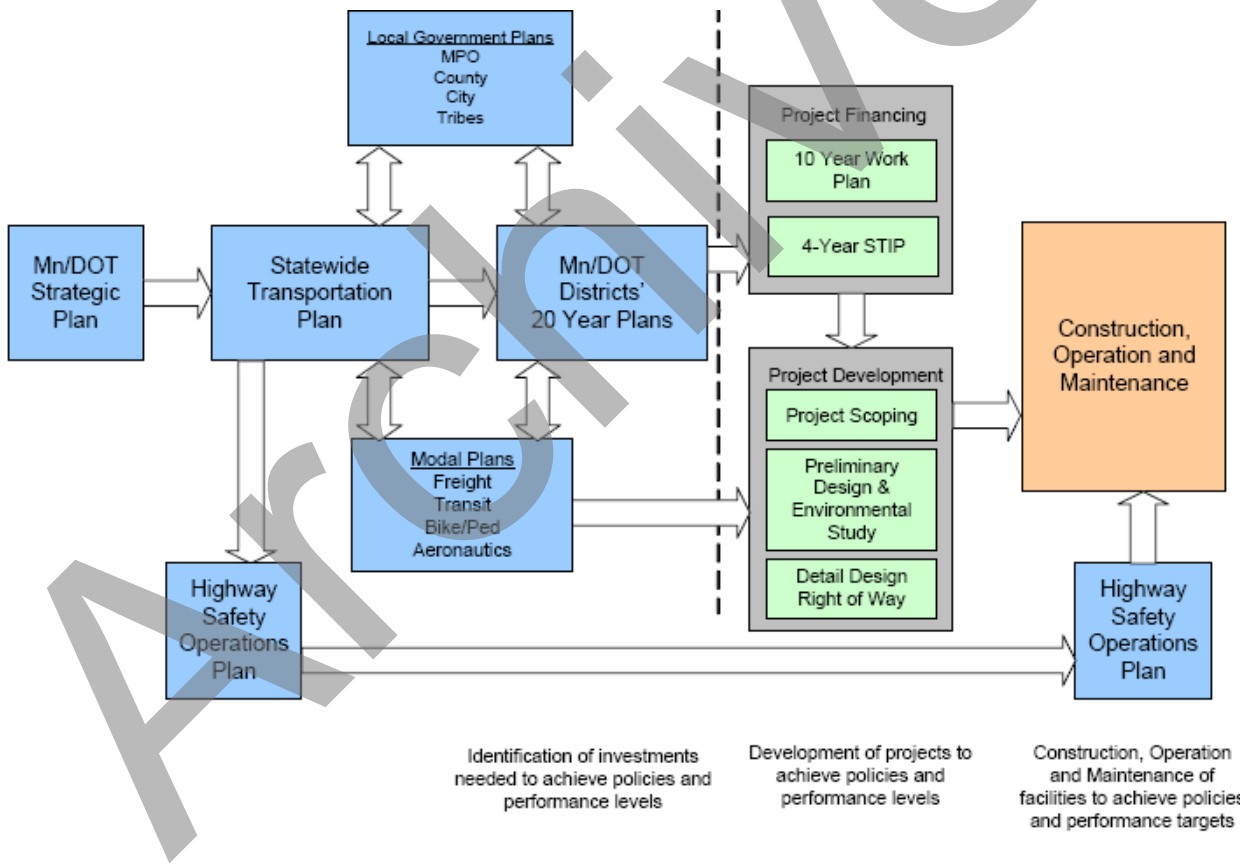

Figure 2. Mn/DOT's planning and programming process.

Mn/DOT reports that the strategic plan is driving its pavement improvement program, but it has taken time to "turn the ship" to align with this philosophy since a number of decision makers remember the availability of funds to support large expansion programs and haven't accepted the reality that current funding levels will not support the same types of programs. An important part of Mn/DOT's strategic plan is pavement preservation and Districts are told to put money in

preservation activities first before other demands and the preservation program is fully funded to support the philosophy. In addition, each District is given a specific performance target to achieve and District Engineers are held accountable for meeting these targets. As a result of these performance-based District plans, Mn/DOT is better able to report "needs" to the legislature, and the available resources are better matched to key performance issues.

The level of acceptance for the information provided by pavement management is admirable. Mn/DOT reports that the Pavement Management Unit has regularly promoted the concepts to the decision makers so the principles are well understood. Pavement management has also made a point of garnering the support of the Material Engineers in each District and getting consensus on any changes that are made to the analysis models. Once the Material Engineers are on board, pavement management seeks the support of the District Engineers and by the time they reach the Planning and Programming Division, they have defused any questions or concerns in the analysis results. As a result there is a high degree of confidence in the pavement management system and an acceptance of the information provided for planning purposes.

UDOT

UDOT is also facing the challenge associated with balancing limited resources with demands for capacity and preservation needs. The agency saw a surge in funding for high-profile projects associated with the State's hosting the Winter Olympics in 2002. However, provisions were never made for the maintenance and operation of these new facilities and so the agency has been placing more of a focus on pavement preservation in recent years.

Pavement management information is used to develop a 20-year program, which is translated into multiple 10-year programs for long-term planning. The information is also used in developing 5-year programs, with four years fully funded and the fifth year updated annually. Politics influences some of the projects that are funded, but the Asset Management Division makes regular presentations to the Transportation Commission to convey the impact of cost increases on the program, the current and projected network conditions, and the funding needs to achieve performance targets. Pavement conditions are reported to the Commission in terms of their Ride Index. Interstate conditions are currently above the condition targets, although the rest of the network is below the targeted condition. It is an ongoing challenge for Asset Management to determine what message should be conveyed to the Transportation Commission and how best to present the message. However, by keeping their decision process very transparent, the Department has been able to build credibility with the Commission over time.

Influence of Pavement Management on Project and Treatment Selection

Pavement management information has become increasingly important to both Mn/DOT and UDOT as competition for funding continues to increase and the cost of raw materials continues to rise much faster than the rate of inflation. Without the availability of the results of objective trend analyses and "what if" scenarios, political influences on project and treatment selection tends to more heavily influence the process than when funding is sufficient to address both political and agency needs. The role of pavement management on the project and treatment selection process in each of the host states is described further.

Mn/DOT

Mn/DOT is an example of a decentralized state, meaning that the Districts have a significant amount of autonomy in the project and treatment selection process. This has had a significant

influence on the role of pavement management in supporting the decision process. In general, pavement management uses its HPMA program to predict pavement performance and to determine what types of treatments are needed in each year of the analysis. Although the Districts have a significant influence on the final selection of projects and treatments, the Pavement Management Unit has established checks and balances to ensure that the appropriate treatment is being placed to address any deficiencies that are identified. The components of the analysis are described separately.

1. Performance Models

There are two types of RQI performance models used in the HPMA analysis: site specific models and default models. The site specific curves are preferred, since they show the deterioration patterns of each individual section, as shown in figure 3. Each year, after the pavement condition surveys are completed, the Pavement Management Engineer reviews the performance models for each individual section to look for anomalies in the data or to determine where maintenance treatments have been performed. In addition, default curves are developed for each pavement type based on statewide historical data. Default models are used when site specific models exceed agency-established rules for the expected performance associated with different treatment types. For instance, if an overlay is expected to perform adequately for 5 to 10 years and the section-specific performance models shows 8 years of performance, then the section-specific curve is used. However, if the section-specific curve predicted performance of 15 years, the default model would be used. The performance of approximately one-third of the network relies on the section-specific curves.

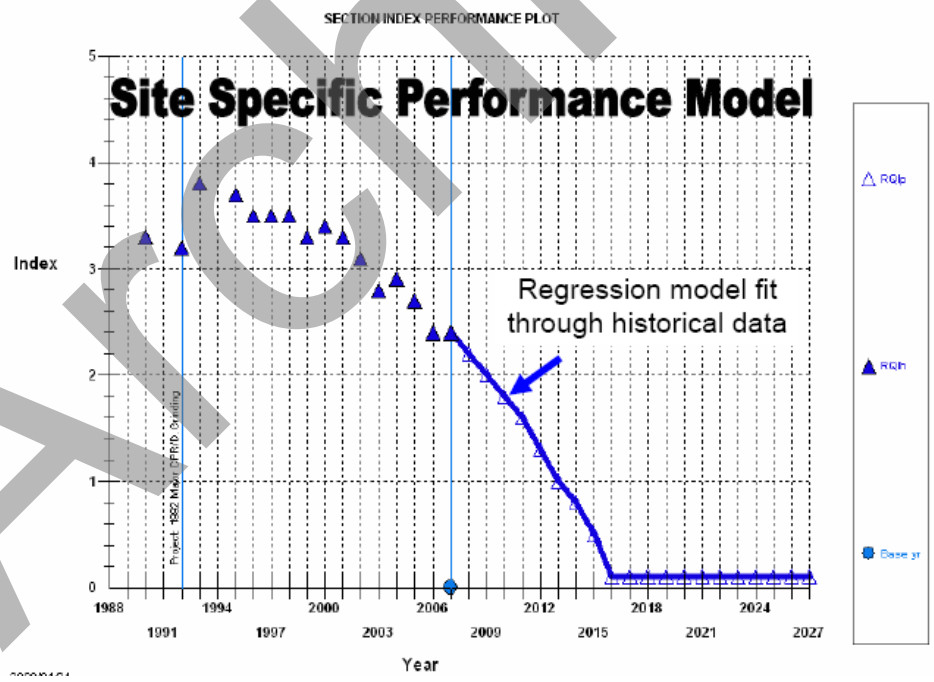

Figure 3. Example of a site-specific performance curve.

In addition to modeling performance in terms of an RQI, performance models for individual distress are also developed since Mn/DOT uses individual distress quantities as a factor in recommending appropriate treatments. Both site-specific and default distress models are

developed, in a similar fashion to the RQI models. The availability of distress models that estimate the percentage of each severity of distress present is an important factor in Mn/DOT's ability to incorporate preventive maintenance treatments into its pavement management analysis.

Periodically, Mn/DOT uses feedback from the field to update its default performance models using an external modeling tool called TableCurve 2D. Perhaps the most obvious outcome of this feedback loop can be seen in the performance curves used after a treatment has been performed. For example, as a result of its field investigations Mn/DOT has adjusted its RQI models to start at values less than a perfect score of 5.0.

2. Treatment Rules

Mn/DOT's pavement management software is used to evaluate preventive maintenance, rehabilitation, and reconstruction alternatives. The treatments listed in table 5 are currently considered in the analysis. Each activity is defined as a construction activity, rehabilitation activity, global maintenance activity, or localized maintenance activity. The type of activity impacts the predicted performance once the treatment has been applied. The HPMA model allows Mn/DOT to reset performance (following the recommendation of a treatment) using an equation, by setting a relative percentage improvement, by holding the condition for a period of time, or by reducing the amount of distress observed. The type of treatment dictates the approach used to reset conditions. For example, an equation that resets the indices to a perfect score can be used for reconstruction projects such as cold in-place recycling, where the original performance of the pavement has little impact on the performance of the treatment. However, for preventive maintenance treatments, where the pre-existing condition is very important, a relative improvement is used. Mn/DOT holds the condition of pavement sections where crack sealing is applied. Once the hold period is over, the pavement then reverts back to the original rate of deterioration. The distress reduction option is used with localized maintenance treatments such as patching.

Table 5. List of treatments considered in Mn/DOT's pavement management software.

Preventive Maintenance	• Crack seal/fill • Rut fill • Chip seal • Thin, non-structural overlay • Concrete joint seal • Minor concrete repair
Rehabilitation	• Medium overlay • Thick overlay • Medium mill & overlay • Thick mill & overlay • Major concrete repair
Reconstruction	• Cold in-place recycling • Rubblized PCC & overlay • Unbonded concrete overlay • Full-depth reclamation • Regrading

The HPMA software has a tool to create decision trees that allows Mn/DOT the flexibility to modify the rules as policies and practices change. Every two to three years, representatives from

the Pavement Management Unit spend a day in the field with the District Materials Engineer to review the types of treatments that are appropriate for randomly-selected sites. The results are compared to the rules used in the pavement management software to help calibrate the treatment rules to actual practice. In addition, this process helps build credibility in the system and results in better acceptance of the recommendations from the pavement management system. Several sets of decision trees have been developed so that different scenarios can be evaluated quickly. Mn/DOT is one of the few states that have developed decision trees for its preventive maintenance treatments in addition to rehabilitation and reconstruction treatments.

3. Analysis Approach

As a decentralized state, the Districts are heavily involved in the selection of projects and treatments. In a typical analysis, District-selected projects are imported into the pavement management system, along with estimated budget allocations, and performance results are analyzed in terms of the RQI, SR, and/or PQI. Where performance targets are not met with the resulting program, adjustments are made or additional funding needs are estimated. Preventive maintenance projects are programmed separately since the Statewide Transportation Improvement Program (STIP) lists a funding level for preventive maintenance rather than list specific projects. Recommendations for preventive maintenance treatments are provided to the Districts using the pavement management decision trees, and the Districts select the final set of projects that will be funded using the preservation funding. The Office of Materials and Road Research must agree that any projects funded with the pavement preservation funding are good candidates to help ensure that the funding is being used for its intended purpose.

In addition to the analysis conducted to develop the STIP, a 20-year maintenance and rehabilitation analysis is also conducted to support the agency's long-term planning and programming activities. In the long-term analysis, the optimal set of projects are selected based on a cost effectiveness ratio that takes into account the additional life associated with a treatment, the length of the project, and a weighting factor (to determine effectiveness) divided by the cost of the treatment. An optimization can be run to determine either the best use of available funding or the amount of funding needed to achieve certain performance targets.

UDOT

There are two factors that influence the project and treatment selection process used by UDOT. First, the Department maintains a database that defines a planned set of strategies for every section, using time-based treatment strategies for different pavement types. While this database in no way dictates the treatments that will be applied, it provides Region personnel with guidelines that reflect the typical timing when different types of treatments are applied. As actual treatments are performed, the database is updated. However, the database is difficult to access and so it provides limited benefit outside the Regions. There are plans to replace this database with a new Pavements module as part of UDOT's new maintenance management system implementation.

The primary source of pavement management recommendations is the optimization analysis conducted using the pavement management system. Details about each of the analysis components are provided in the following three subsections (i.e., 1. Performance Models, 2. Treatment Rules, and 3. Analysis Approach). A steering committee comprised of Pavement Management staff from the central office and the Region Pavement Management Engineers was involved in the original development of the treatment rules and continues to be involved in any changes that are made to the models. This involvement of Region personnel has had a

significant impact on the level of acceptance of the recommendations that are generated and has provided a solid basis for understanding the operation of the pavement management system.

1. Performance Models

Pavement performance models have been developed based primarily on engineering judgment for pavement families that contain pavement sections with similar rates of deterioration. Pavement families are defined based on pavement surface type (gravel, PCC, and HMA) and traffic (including interstate, high speed routes [> 50 mph], medium speed routes [40 to 50 mph], and low-speed routes [<40 mph]. In total, UDOT has nine pavement families. Deterioration models have been developed for each condition index within each family. For example, there are four performance models for the high-speed asphalt family representing the ride, rutting, cracking, and wheel-path cracking indexes.

2. Treatment Rules

A variety of treatment types are considered in the pavement management analysis, as shown in table 6. The Department continues to work on refining the rules for selecting each treatment, with current efforts focused on improving the PCC treatment rules.

Table 6. List of treatments considered in UDOT's pavement management software.

PCC Treatments	• Concrete grinding • Concrete minor rehabilitation (such as dowel bar retrofits and slab replacements) • Concrete major rehabilitation and reconstruction
HMA Treatments	• Low seal (such as chip or slurry seal) • Medium seal (such as microsurfacing or a hot-applied chip seal) • High seal (such as an open-graded surface or a Nova Chip) • Functional repair (including patching & milling followed by a thin (1.5 in) overlay) • Asphalt minor rehabilitation (Mill and replace or thin (3-4 in) overlay) • Asphalt major rehabilitation and reconstruction

The three different types of seal coats considered on HMA pavements were added within the last year to enable pavement management to better estimate project costs. The appropriate type of seal is selected based on project location (in terms of an urban or rural environment), functional class, and traffic volume. In general, seal coats are applied to pavements in good condition with indexes between 70 and 100. A high seal is applied to pavement sections with traffic in excess of 15,000 vehicles per day and a low seal is applied on pavement sections with less than 7,000 vehicles per day. Medium seals are used on pavement sections with moderate traffic volumes that fall between the other ranges. The decision process for selecting the appropriate seal is shown in figure 4.

Minor rehabilitation activities are generally recommended when pavement condition indexes are between 50 and 70 and the rehabilitation/reconstruction treatment is triggered when the pavement condition indexes fall below 50. In the past, rehabilitation and reconstruction treatments were triggered separately, but because of the low number of reconstruction projects

being funded, they were recently combined into a single treatment in the analysis. Treatment costs are estimated using both recent bid prices and Region input. The pavement management system allows for an inflation rate to be applied to future costs and provides for costs to be differentiated for rural and urban situations.

Reset values for each treatment are based on an estimate of time for the road to return to the condition at the time the treatment was applied. Separate reset values have been established for each treatment and each index. For example, a low seal resets the conditions in five years while a medium seal might reset the conditions in seven years.

3. Analysis Approach

The pavement management software is used to conduct at least three types of analyses. For example, an iterative process is used to determine the recommended level of funding based on the projected conditions under each scenario. This type of analysis is conducted by inputting different budget levels into the analysis and evaluating the overall distribution of network conditions achieved. By comparing the results from several budget levels, a recommended funding level can be determined to meet system level goals and strategies.

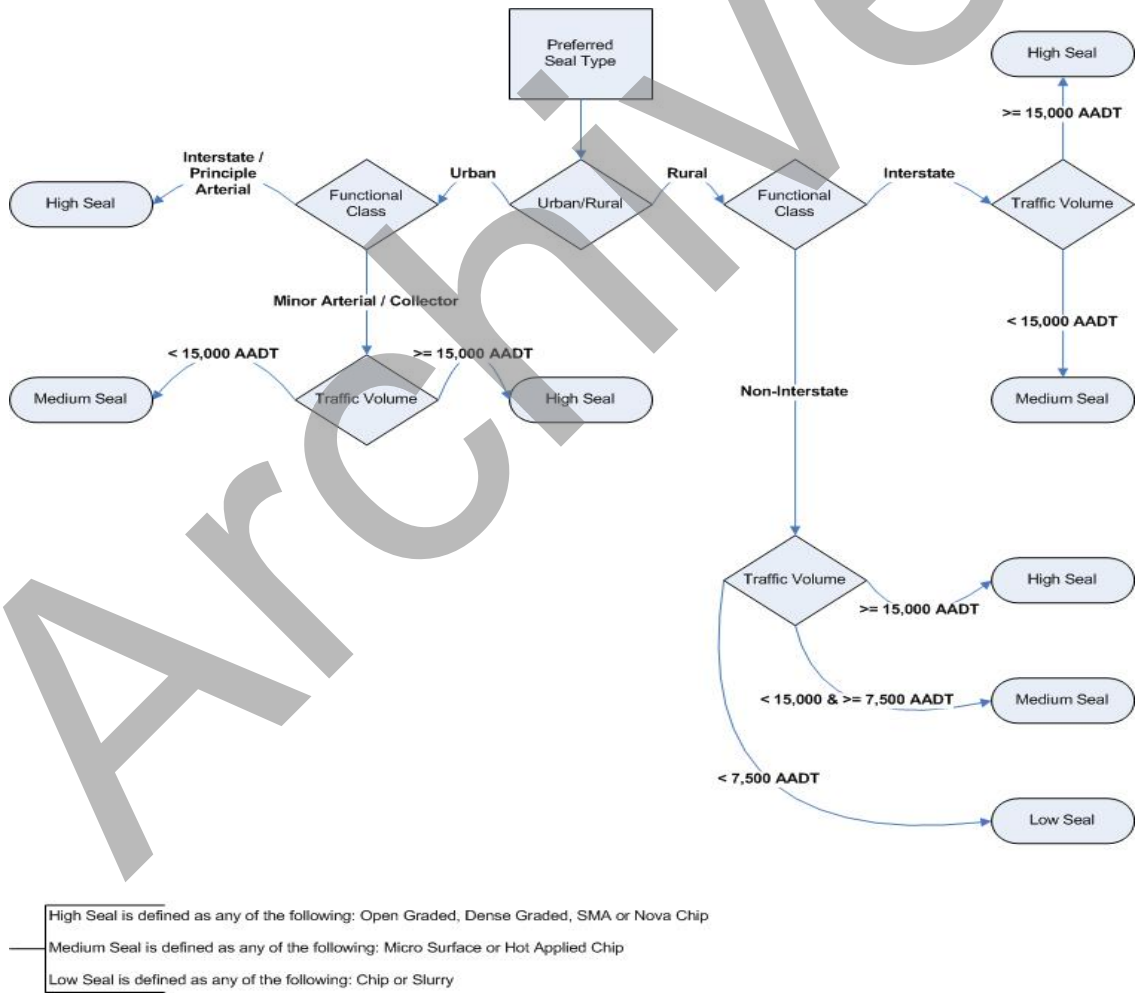

Figure 4. UDOT's decision process for selecting the preferred seal.

Once funding levels are set, the pavement management analysis is used to set Region budgets from an assessment of needs in each Region. After Regional budgets are set, five years of

candidate projects are recommended for funding using the outputs from the pavement management system. Regions either accept or justify the selection of other projects for the program, and the central office fits the proposed projects to funding availability by eligibility and makes the final allocations of funds to each Region. The Regions are responsible for managing their programs within the funding allocated to them. Depending on the Region, the projects selected by the Regions usually closely match those recommended through the pavement management analysis. Questions in data quality has limited one Region's match to about 50 percent, but most of the other Regions report a match closer to 70 or 80 percent.

The pavement management analysis results are used to develop project recommendations for the *Orange Book*, which includes pavement preventive maintenance projects and simple resurfacing projects intended to address functional improvements only, the *Purple Book*, intended to address minor rehabilitation, and the *Blue Book*, which funds major rehabilitation and reconstruction projects. Projects of all three types (*Orange Book*, *Purple Book* and *Blue Book*) can be funded using either state or federal funds, or may be funded by a combination of the two sources.

Information from the pavement management system is provided to the Regions to use as guidance in selecting projects and treatments that make the best use of available funds. To help aid the buy-in of Region personnel in the recommendations from the pavement management system, UDOT has offered 1-day training sessions, conducted field visits with Region personnel to review treatment recommendations, and involved the Regions in the refinements to the pavement management models. UDOT now reports that Regions are coordinating their program with pavement management and the project cost estimates are now more in line with the actual costs in the field.

Because of the limited funding levels available for pavement preservation in recent years, UDOT is developing a process for identifying certain routes as "Maintenance Only" sections in recognition of the fact that many low-volume rural routes were not a high enough priority to be funded for rehabilitation or reconstruction. Under this approach, these sections will be maintained using only patching and chip seals and the pavement management software will not recommend any other treatments. Although the strategy for incorporating these sections into the pavement management analysis has not been finalized, initial estimates indicate that as much as 20 percent of the system could fall within this category due to limited funding availability.

Use of Pavement Management For Non-Traditional Applications

Up to this point, the report has documented the more traditional use of pavement management programs to support the identification and prioritization of pavement maintenance and rehabilitation needs. However, the host states selected to participate in the Peer Exchange have successfully used their pavement management information to support other types of analyses. These additional applications are discussed in this section of the report.

Engineering and Economic Analysis

UDOT pioneered the concept that maintaining roads in good condition was less expensive than allowing them to deteriorate to the point that substantial improvements were required. A report documenting these findings was published in 1977 and it quickly became an important reference for agencies with a strong focus on pavement preservation. The message published in 1977 is equally important in 2008 as agencies face increasing raw material costs and decreases in available funding. Therefore, in 2006 UDOT used its pavement management data to update its

Good Roads Cost Less study (Report Nos. UT-06.15 and UP-06.15a). As part of this updated study, the pavement management system was configured to evaluate several different treatment strategies for pavement preservation. The effectiveness of each strategy was evaluated in terms of pavement condition, agency costs, user costs, delay costs, and safety. The results of the analysis were used to establish updated performance targets that set realistic expectations under the current economic climate. The results found the following (Zavitski et al. 2006):

- A highway network in poor condition has a direct impact on the economy and citizens of Utah through increased accident, delay, user, and agency costs.
- Lowering the network condition by as little as 10 to 20 percent will cause a funding crisis as the need for more expensive rehabilitation treatments will force UDOT into finding alternate funding solutions.
- Diverting funding to support improvements for work other than pavement maintenance and rehabilitation (such as capacity projects) will lead to a decrease in overall network conditions that will require significant funding to address.
- Current funding is sufficient to maintain the UDOT network in good condition, but would be insufficient to restore the network to good condition if a 10 percent drop in network conditions were to occur.
- Pavements that are in good condition today can be maintained using an appropriate mix of minor maintenance, preservation, and rehabilitation treatments that maximize the OCI and prolong the life of the pavements. Higher conditions were able to be achieved when budget category restrictions were removed, indicating that more flexibility in funding for preservation treatments can lead to improved network conditions.

UDOT is in the early stages of determining how the pavement management database can be used to support future requirements for the calibration of the new Mechanistic-Empirical Pavement Design Guide (MEPDG) developed through research by the National Cooperative Highway Research Program (NCHRP). Initial efforts to prepare for the implementation of the MEPDG are focused on evaluating the performance data to determine its reliability for this application.

The University of Minnesota performed some initial work to investigate the feasibility of calibrating the MEPDG models using Mn/DOT's pavement management data. The Pavement Management Engineer reports that Mn/DOT has most of the data needed for the MEPDG implementation (including a comprehensive pavement treatment history), with the possible exception of fatigue cracking data. Mn/DOT's pavement condition survey procedures were developed using a distress called "multiple cracking," which can be a combination of block cracking and fatigue cracking. A recommendation for how to handle this distress in the MEPDG models had not been developed at the time of the Peer Exchange.

Mn/DOT reported that its pavement management software has been used to conduct a number of different types of economic and engineering analyses. For instance, one engineering study investigated the performance of a full-depth HMA design that repeatedly had performance issues when it was place directly on the subgrade rather than on a gravel base. As a result of the analysis, a moratorium was placed on the design.

Pavement management information has also been used by Mn/DOT to conduct a number of different types of economic analyses. For instance, approximately five years ago Mn/DOT revisited its life-cycle cost analyses (LCCA) to incorporate preventive maintenance treatments

into the treatment strategies evaluated during Design's pavement type selection process on reconstruction projects. Using construction histories from pavement management, Mn/DOT was able to support the revisions to its LCCA process when industry questioned the treatment cycles. The availability of actual data to support its recommendations was important to the successful adoption of the proposed changes.

Pavement management "what if" scenarios have also been used to support different types of economic studies for the Department. For instance, the Division Director once questioned spending money on good roads when funding was insufficient to address the performance targets for roads in poor condition. The results of the 20-year analysis from pavement management were used to demonstrate the importance of preventive maintenance, but were also used to set budget levels for the program. In another example, the Governor proposed a big bonding program and pavement management analyzed the impact of the funding. One step in the process involved asking the Districts how they would spend the additional funds if they became available. Pavement management found that most of the Districts planned to use the funds for expansion projects rather than preservation projects so the net result of the funding would have little impact on improving pavement conditions.

Other types of economic analyses have helped the Department establish the performance targets included in the strategic plan. The Pavement Management Unit has used the software to evaluate the impact of changing the definition of "poor," lengthening the time to reach the performance target, and optimizing funding by maximizing the number of pavement sections that are kept from falling into the poor condition. The results of this type of analysis are increasingly important to keep the Districts from diverting from their preservation strategy.

Links to Asset Management

UDOT is working with Deighton and Associates to develop an investment strategy tool that will enable the Department to quickly assess the impacts of changes in investment levels for its assets. Currently envisioned to include funding for pavements and bridges, other assets can be included in the future. As it is currently planned, the tool will be preloaded with the results from several investment strategies for each asset using the bridge management and pavement management programs. The tool will enable upper management to quickly determine how a change in an investment for one asset impacts the level of service provided to other assets. One of the greatest challenges to this approach is developing a method of quantifying the benefits associated with different assets and developing relationships that allow them to be compared on an equal basis.

Availability of Data to Support Other Needs

Pavement management information is often used to support other types of reporting and analysis needs within a transportation agency. At the national level, IRI information is reported annually to the FHWA as part of its Highway Performance Monitoring System (HPMS) program. A reassessment of the HPMA requirements is currently underway and early indications are that more detailed information about the National Highway System (NHS) routes in each state will be required. Because of the comprehensiveness of its pavement management and TIS databases, Mn/DOT does not anticipate any difficulty in being able to respond to the additional data requirements. Because of some of the changes UDOT is initiating to its data collection procedures (to change from the manual collection of distress information to automated collection) the anticipated impact of the reassessment on their agency is less clear.

Support of Upper Management

Both of the host agencies visited during the Peer Exchange stressed the importance of upper management support to the success of their pavement management activities. This support is important not only for providing the resources needed to support pavement management activities, but also to provide support for the recommendations from the pavement management analysis. The true measure of upper level support is reflected in the degree to which pavement management recommendations are influencing investment decisions and project selection decisions in the agency.

Both Mn/DOT and UDOT have strong support from upper management for their pavement management systems. Mn/DOT has built a high degree of confidence in its pavement management program by regularly communicating the principles of pavement management with decision makers and by building consensus among agency staff. For example, when changes to the pavement management program are envisioned, the Pavement Management Engineer talks with the District Materials Engineers to gain their support. Once they are supportive of the changes, the Pavement Management Engineer obtains the support of the District Engineers by discussing the proposed changes and the underlying assumptions. By the time the information is presented at the upper levels, most of the questions that could be raised have been defused and the recommendations are accepted fairly easily. Upper levels within the Department are now engaged in the pavement management process and the degree to which pavement management information is used to support the Department's Planning and Investment Management activities is impressive. During the Peer Exchange, the representative from the Planning, Modal, and Data Management Division regularly used pavement management terms and promoted the importance of pavement preservation within the strategic plan.

In UDOT, the Director of Systems Planning and Programming and the Director for Asset Management regularly present information regarding network conditions and funding needs to the Executive Director, the Budget Director, and the Utah Transportation Commission. UDOT reports that the Transportation Commission considers the pavement management system very credible, as evidenced by the decision to use the pavement management analysis results as the basis for allocating funding for the Orange Book program to the Regions. Their confidence in the system has developed over a long period of time. Approximately 30 years ago, UDOT pioneered the message that keeping roads in good condition for a longer period of time was a more cost-effective strategy than letting the pavements deteriorate. Each year a workshop is conducted to reinforce this message and it is now well understood by the Commission and individuals throughout UDOT.

Staffing and Other Resources

Both Mn/DOT and UDOT are fortunate to have adequate resources to support their pavement management activities. In both agencies, the engineers responsible for data collection and analysis have been with their Departments for many years. Each organization also has at least two people familiar with the software, which reduces the risk of obsolescence if the sole analyst is no longer available to operate the software.

Mn/DOT's pavement management staffing consists of a statistician, a Preventive Maintenance Engineer, a technician (to perform data quality checks and GIS mapping), and the Pavement Management Engineer. In addition, there are four individuals who operate the Department's two data collection vans and who are responsible for collecting pavement condition data on both the

state highway system and the state county road system. The field crew/raters are supervised by an Engineering Specialist who is also responsible for processing the pavement condition data.

There are approximately 30 users of the HPMA software, if personnel in the District offices are included. Each year, training is provided to Regional and District personnel with one day covering the pavement management program and another ½ to 1 day on optimization. Because of the infrequency with which the Districts use the program, they frequently rely on the central office to provide information, but the training provides District personnel with the background needed to be familiar with the logic behind the analysis.

One of the keys to Mn/DOT's success with its pavement management system is the consistency in pavement management personnel. For the past 10 years or so, the Pavement Management Engineer for Mn/DOT has been operating the pavement management system on a daily basis. This has been very good for the Department, and has provided a great deal of consistency to the program. Although others in the Department are familiar with the software, there is no one on staff with a more intimate understanding of the pavement management program than the Pavement Management Engineer.

UDOT's Asset Management Division includes 9 people, including the Director of Asset Management. Included in this Division are four pavement management engineers, one asset management engineer, and a data collection team comprised of one engineer and two technicians (the photolog is not the responsibility of the Asset Management Division). In addition, Pavement Management Engineers are located in each of the four Region offices. At one time, UDOT had copies of the pavement management software in each Region for the Region Pavement Management Engineers to use. However, because the amount of turnover in these positions and the complexity of the software, the pavement management software is currently operated by the central office staff. As a result of the involvement of the Region Pavement Management Engineers in changes to the pavement management program through the Steering Committee, they understand the pavement management activities philosophically even though they no longer operate the software. UDOT found that the software needs to be used on an almost daily basis to avoid forgetting the subtleties of its operation. When it was used only occasionally, the amount of time required for the Region Engineers to get back up to speed deterred them from using the information. Now, the Regions frequently request information from the central office pavement management staff. To assist in providing the most requested information efficiently, the Department is investigating strategies for storing some pavement management information in the Department's new maintenance management system, since it will be more familiar to Region personnel.

The support of the Regions is considered critical to the success of the UDOT pavement management activities so the participation of the Region Pavement Management Engineers on the Steering Committee is an important form of outreach. By participating in these types of activities, the Regions better understand the Department's pavement preservation philosophy and the assumptions upon which the pavement management results are based. This has been an important factor in the success of UDOT's pavement preservation program.

Funding for pavement management activities has enabled UDOT to purchase data collection equipment, including an ICC profiler, a Mandli photolog system, skid equipment, and a Jils truck-mounted FWD. In addition, funds have been provided for photo logging. As stated elsewhere in the report, UDOT is in the process of hiring a vendor to collect pavement condition

data in the future, so the amount of data collected by in-house staff is expected to change in the future. However, the amount of funding budgeted for data collection activities is expected to remain at approximately the same level. UDOT also pays a licensing fee to its software vendor and has a $125,000 retainer for the vendor to conduct training several times a year. Special projects, such as the investment tool that is under development, are funded separately.

Future Activities/Directions

The implementation of a pavement management system is not a static process and even agencies that have strong pavement management programs in place regularly make adjustments to keep the models current. Some of the developments that are taking place in Mn/DOT and UDOT are summarized below.

- Using pavement management information to set District funding levels – This change is expected to take place in Mn/DOT by the time the next funding cycle occurs. UDOT currently uses the pavement management results to set the funding levels for the Regions' Orange Book program.

- Determining a reasonable investment level to preserve asset conditions – UDOT estimates that it is investing approximately 1.9 percent of the value of its pavements in maintenance and rehabilitation. Participants expressed interest in determining whether this investment level is reasonable and whether it compares to the level invested by other states. Targeted investment levels of 2 ½ to 3 percent of asset values were discussed.

- Determining how to best convey funding needs to decision makers and politicians – Although Mn/DOT and UDOT regularly present pavement management results to decision makers, they are regularly improving the reporting process to ensure the right information is conveyed quickly.

- Determining the effectiveness of preventive maintenance – Mn/DOT is initiating work to demonstrate the effectiveness of its preventive maintenance activities using control sections.

- Identifying strategies for addressing decreasing funding levels – UDOT is considering a process for identifying "Maintenance Only" sections that will receive no treatment more substantial than a chip seal.

- Strengthening the link with Maintenance and Operations – UDOT is considering the use of the Pavements module within its new maintenance management system to store maintenance work history activities. This change is expected to improve the accessibility of this information within the Department.

- Improving treatment decision rules – UDOT expressed interest in developing a structural number that can be used in treatment decisions based on the FWD test data collected as part of the pavement management activities. In addition, UDOT expressed interest in improving its PCC treatment rules.

Software Selection and Procurement

UDOT first acquired their current pavement management software from Deighton and Associates in the late 1990s. The vendor installed the software and provided links to any

existing agency databases and to load data, but the Department elected to develop its analysis models using its Steering Committee. The Steering Committee met monthly to review progress during the initial development and in-between meetings the pavement management staff would use the software to run scenarios to evaluate the reasonableness of the models. This approach may have taken more time than allowing the vendor to develop the initial models, but it provide UDOT with one form of training that made it easier to understand how the analysis worked. Additionally, since UDOT's models were going to be developed based on expert opinion, the Department had more confidence in their ability to develop representative models than in the vendor's ability to do the work.

Mn/DOT's pavement management software has evolved over time from a FORTRAN program installed in 1987 by PMS Ltd to a MS Windows application in 1995 by Stantec (the company that purchased PMS Ltd.). There have been several enhancements to the software since 1995.

Lessons Learned

Some lessons were learned as a result of the software selection and procurement processes used by Mn/DOT and UDOT:

- Guard against using a beta version of the software. Be sure the program has been used in other state applications before being installed in your agency. Ask to see screens that contain real data so you can see what they look like when they're populated and you can evaluate the ease with which the software operates. Ask the vendor to demonstrate the software using data from another state rather than try to load sample data from your own state. This way, the vendor is not limited in demonstrating the full range of functionality because of partial or incomplete data sets.

- The models incorporated into the pavement management system should reflect the way your organization does business. For instance, UDOT created their decision trees to recommend treatment categories rather than specific treatments because it better matched the way they do business. Now, the pavement management system can be used to determine the level of repair necessary and the approximate amount of funding required, but the selection and design of the final treatment is left to the Regions. Over time UDOT found that they needed to separate out their seals in more detail than they had originally to better estimate project costs, but only minor adjustments have been needed to the other models.

- Key items or functionality that state highway agencies should look for in a system include:

    - Flexibility – A pavement management system is not like "TurboTax©" where you can open it up and start using it immediately. It needs to be customized to the agency's policies and procedures and must be able to be modified (without vendor support) to reflect changes with time.

    - Technical Support – There is a lot of time spent on customization activities during an implementation project to match the software capabilities to your agency's processes. Be sure the vendor is available to provide that level of support during the initial project and in future years. Get the support of Information Technology

(IT) personnel to make sure the software runs on your agency's network and environment.

- Check references and talk to the people who actually operate the software. They will provide you with an honest assessment of the ease with which the software can be used and the logic behind the user interfaces.

- Identify the process the vendor uses to update the capabilities of the software. Is the process driven by users, or does the vendor decide what updates will be added? Determine how frequently updates are issued and what requirements are in place for obtaining a copy of the new version.

- Verify that the information from the pavement management system can be easily exported into other programs such as Excel or GIS. Both of the host agencies reported frequent use of external programs to analyze or present the pavement management information rather than use the capabilities internal to the system.

- Ask about the process for importing the final program into the pavement management system, especially in a decentralized organization. In some instances, the final list of projects and treatments has to be entered manually if substantial changes are made to the recommendations produced during the pavement management analysis. Ideally, the software has a tool that allows the agency to export the recommendations from pavement management to another program where they can be manipulated before being imported back into the pavement management system to determine future conditions.

Institutional or Implementation Issues

The success of the pavement management program in the host agencies has not occurred without having to deal with several institutional or implementation issues. These types of changes are to be expected especially if the pavement management process leads to changes in the agency's policies and practices. For instance, the incorporation of preventive maintenance treatments in a pavement management system requires a corresponding shift in funding allocations and philosophy. The types of issues these agencies have faced, or are continuing to face, are discussed in this section of the report.

One of the most significant institutional issues being faced by the host agencies is shifting the focus of the agency from expansion to preservation in response to the changes in available funding for transportation activities. Not only are the dramatic increases in the cost of raw materials (such as asphalt) impacting the number of miles of highway that can be paved, but other funding sources are also failing to keep pace with the increasing infrastructure needs. For instance, Mn/DOT reports that its pavement conditions are deteriorating due in response to the funding climate. As a result, the current strategic plan places more of an emphasis on preservation activities than on expansion projects and strong, defensible pavement management practices are increasingly important to the agency. Not only does pavement management help determine the best use of available funds, but it also provides the justification for budget requests. Pavement management also provides the documentation needed to demonstrate to decision makers that the agency is accountable for the funds that are provided. The increased emphasis on pavement management to support the agency's long-term planning was specifically noted during Mn/DOT's presentation.

There were several other specific institutional and implementation issues that emerged during the presentations by the host agencies, as listed below.

- Mn/DOT reported that their strategic plan is really driving their transportation program, but it took a number of years for this change to take place and a strong commitment from the top to stay the course.

- UDOT expressed interest in having dedicated funding for preventive maintenance activities so it is not such a fight to secure the funding for these activities each year. Currently, most of the funds for these types of activities are vulnerable and may be shifted to address other needs or priorities. The portion that is actually dedicated to preventive maintenance is a very small portion of the budget being spent on these types of treatments.

- Both organizations benefited from pavement management personnel who have worked in pavement management for many years.

- It is important to fight the worst-first mentality that is often pervasive in Regions or Districts. It is important to get field personnel to understand that a Region priority may not be the same as a statewide priority and the challenge at the network level is to balance these competing priorities. UDOT has conducted some scanning tours with its Pavement Management Engineers in an attempt to convey this message. As a result of these tours they found that different people approach projects from different points of view. These differences need to be checked and addressed regularly.

- Over time, the level of acceptance of the pavement management recommendations has been improving. UDOT provides the Regions with a 5-year window for addressing recommendations that are generated by the pavement management system, with the exception of pavement preservation projects that should be addressed within a 3-year window.

- Pavement histories can provide very valuable information, especially in determining the right treatment for a pavement section. Mn/DOT has built a very comprehensive pavement history database that is available to anyone within the Department. UDOT's construction history is less complete and relies on updates by the Region engineers prior to running an analysis. This has caused problems at times because the data have not always been provided on a timely basis. However, UDOT plans to overcome this hurdle by including the work history in the new maintenance management system that is being implemented. The new program provides better accessibility to the information throughout the Department.

- It is important to coordinate the timing of automated pavement condition surveys by the vendors with the timing of construction projects so the pavement management database reflects current information. For instance, UDOT is deciding whether to collect the pavement condition data after the construction season (so the surveys reflect the improved conditions) or whether a process will be developed to update the data when surveys have been conducted prior to the construction season.

- The complexity of the system may impact your ability to respond quickly to queries from upper management about the consequences of various actions. Therefore, agencies have had to balance the need for technical sophistication with practical constraints for operating the software. For example, it takes UDOT approximately 6 hours to run a full analysis, but the length of time is dependent on the number of analysis parameters considered, the number of sections being analyzed, and the length of the analysis period. If the ability to respond quickly to questions about the impact of changes to the program is an important consideration, then compromises may have to be made in setting up the system that favor speed over function.

Key Success Factors

The two host agencies that participated in the Peer Exchange were selected, in part, because of the degree to which pavement management information is used to support agency decisions. Some of the keys to the success of the pavement management programs in these agencies are listed below.

- Maintain consistency in pavement management personnel – Both of the host agencies have benefited from the consistency in their pavement management staff. These individuals are very familiar with the operation of the software and have gained confidence in the data used to make program recommendations.

- Use quality data – For the agency to build confidence in the pavement management program recommendations, it is important that the data used in the analysis are defensible and the analysis models reflect the agency's deterioration rates and treatment rules.

- Develop a strong, cooperative relationship with your software vendor – This has worked to the advantage of both of the host agencies. In Mn/DOT, they can call the vendor's programmer directly if there are problems that arise. In Utah, the relationship with the vendor has allowed them to strategize about the timing of upgrades to their software and to expand the system capabilities to include asset management.

- Regularly promote pavement management concepts – The individuals influencing the investment and project selection decisions in transportation agencies change on a regular basis. Therefore, it is important that pavement management personnel continually communicate pavement management concepts, and the results of the optimization strategies, to decision makers, politicians, transportation commissioners, transportation planners and programmers, and District Engineers to ensure that the principles are well understood.

- Build consensus for the analysis models – Both Mn/DOT and UDOT have involved District and Region personnel in the development of the initial pavement management models and any changes that have been made since the initial implementation. The involvement of field personnel in Steering Committees or Technical Panels helps build credibility and acceptance of the analysis results.

- Implement tools with flexibility – As demonstrated by both of the host agencies, there are a number of different factors that influence the funding available for pavement maintenance and rehabilitation, the types of strategies considered, and the traffic patterns on the state system. As a result, a pavement management program must be flexible

enough to be able to adapt to these changes fairly quickly. For example, Mn/DOT was able to incorporate preventive maintenance treatments into its pavement management analysis to some degree because of its use of individual distress data in its decision trees. The availability of this information allowed them to develop rules for triggering preventive maintenance treatments and for resetting the condition indexes after the treatments had been applied.

- Continue to improve your system with time – The implementation of a pavement management program requires a commitment in time and resources to continue to enhance the quality of the data and the accuracy with which the models can forecast future conditions. Agencies should commit to the software licenses that keep their pavement management program current and to participation in conferences and/or user groups that foster innovation and improvements in the way business is conducted.

Benefits Realized

To a large degree, the benefits associated with the implementation and use of a pavement management program are subjective and difficult to quantify directly. However, each of the host agencies identified several benefits they feel are largely the result of the quality of the pavement management program. Some of these benefits are described below.

- UDOT reports that one of the benefits they realized from their asset management efforts is the improved analysis capabilities for managing their bridges. Using pavement management as a model, UDOT worked with its bridge engineers to significantly improve their ability to analyze current and future bridge needs.

- Mn/DOT has been able to make the conversion to an organization that places system preservation as a priority. The strategic plan supports the preservation of existing assets and the investment allocations support these efforts. Pavement management information has provided important support during this transition.

- Both agencies report having better information to support the decision processes due to the availability of reliable pavement management information. Mn/DOT reports that the greatest reward from the system has been their ability to demonstrate the amount of road deterioration that can be expected with various levels of budget cuts. Additionally, the impact of large expenditures on expansion projects is able to be forecast immediately.

- Economic and engineering analyses are supported through the availability of field data to evaluate treatment performance.

- Pavement management has been able to provide useful information to Region and District Engineers responsible for project and treatment selection decisions. On a day-to-day basis, the pavement management system has enabled these agencies to more efficiently sort through the pavement data to determine candidate projects.

- On a grand scale, the agencies report that their pavement management programs have enabled the agencies to use money more effectively, which has resulted in the best possible conditions for the funding levels available.

CONCLUSIONS

The participants in the Peer Exchange were unanimous in their praise for the activity. Collectively, the participants from the participating agencies felt better prepared for the implementation activities they would be conducting and appreciated the ability to query actual users of the software. The host agencies also benefited from the program through the opportunity to ask questions of the participating agencies to compare and contrast current practice. The program successfully accomplished its mission to share information among pavement management practitioners. Some of the feedback provided by the participants is included in this section of the report.

- The information helped prepare the participating agencies for the implementation of their new software. The participants felt that they had a better handle on the types of issues they would be addressing and the factors that would most contribute to the success of the project. Prior to the Peer Exchange, some participants felt that they "didn't really know what they needed to know." After the Peer Exchange, they had a much better feel for the implementation process and how the system might be used within their agency.

- By bringing together agency representatives from different divisions, the Peer Exchange was able to touch on the use of pavement management to address the varied needs from throughout the organization. Participants left the meetings with a greater appreciation for the expansive knowledge that is incorporated into a successful pavement management system.

- The Peer Exchange demonstrated that there is no single approach to a successful system. However, MnDOT and UDOT demonstrated their ability to blend reliable data for use in their analysis and to foster two-way communication of the results with decision makers. The Pavement Management Engineers from these agencies "owned" the process and were critical to achieving good results.

- The opportunity to talk with users of the various systems was identified as being particularly useful to learn more about how the systems are actually being used.

- It is important to see the degree to which pavement management is integrated into the decision processes in each of the host agencies. This helped emphasize the importance of the integrated approach to a successful implementation and the importance of having credible data.

- The Peer Exchange provided an opportunity for the participants to identify possible pitfalls to a successful implementation to better identify what to watch for.

Next Steps

The two February 2008 Pavement Management Peer Exchange sessions were the first Peer Exchange meetings organized by FHWA on this subject. In addition to providing benefits to the participants in the meetings, the FHWA supported the development of this report to provide a mechanism for transferring the technology to other pavement management practitioners. The remaining sections of the report outline specific plans for the FHWA's technology transfer efforts and the planned implementation activities within each of the participating agencies.

FHWA

The FHWA currently plans to conduct additional Peer Exchanges on the subject of pavement management in the future. The focus of future Peer Exchanges and the exact format that will be used have not yet been determined. In addition, the FHWA will use the contents of this report to help promote the effective use of pavement management tools. The report itself will be distributed to all state Pavement Management Engineers and to the FHWA Division Offices. FHWA also envisions using excerpts from the report in magazine articles (such as *Focus*) and presenting some of the information in a web conference.

Participating Agencies

The New York DOT and Caltrans are both embarking on their plans to enhance their existing pavement management capabilities as described in the following sections.

New York DOT

NYSDOT prepared a draft work plan in May 2007 that outlines their plans for enhancing their existing pavement management system. The plan provides a background summary and the steps that will be taken to obtain new software.

Purpose -

Continue the development of the Department's Pavement Management System by modernizing the existing modeling software, which is now obsolete, with a commercial system having more robust modeling capabilities and analysis tools needed to economically manage the state's pavement network.

Background -

PNAM (Pavement Needs Assessment Model) is the Department's current software program used to forecast pavement conditions and funding needs. The system was developed in-house in the 1980s and has performed well over the years for its intended purpose. However, the program has been tweaked and stretched to its practical limit in an attempt to keep up with the growing sophistication of pavement management technology. The modeling and analysis demands of the maturing pavement management process have now exceeded PNAM's capability.

In addition, the software platform on which PNAM is built is no longer supported by the manufacturer. This loss of support is further compounded by the retirement of the original programmer and the loss of the operating experts. The system is vulnerable to becoming inoperable and the Department will not have the ability to forecast pavement conditions and needs. A replacement for PNAM is needed to properly manage the pavement network and to allow the Department to incorporate current pavement management technology in the decision process.

Action Steps -

Action / Deliverable Start Finish

1. Issue RFI to obtain information on status of technology for input to development of RFP. 4/12/07 5/24/07

2. Form PMS Evaluation Committee. 6/1/07 6/30/07

3. Invite selected vendors to make detailed presentations of their systems (RFI only). 7/1/07 10/15/07

4. Develop IT Project Proposal. 8/15/07 9/15/07

5. Submit Proposal to IT Governance Council for funding/project approval.

6. Develop RFP documents (Narrative, Specification, Evaluation Criteria).

7. Advertise RFP.*

8. Evaluate Project Proposals from vendors through RFP process.

9. Select vendor and award contract.

10. Begin system implementation.

* Schedule from this point forward is controlled by funding approval.

Caltrans

Since May 2007, Caltrans has been investigating solutions that will result in better tools for managing its pavement network. An agreement has been reached between Caltrans and a South African company to implement a customized version of the Deighton & Associates dTIMS software that will be modified slightly for Caltans' use. With that decision made, its pavement management personnel are moving forward with data collection contracts for both a structural evaluation, which will include Ground Penetrating Radar and Coring, and a condition assessment. The Department's efforts will be supported by faculty at the University of California at Berkeley.

The most immediate activity for the State Pavement Program Manager is to secure the funding needed to support these pavement management activities. Caltrans hopes to have funding secured within calendar year 2008 and plans to have the implementation completed by the end of calendar year 2010.

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APPENDIX A – PEER EXCHANGE AGENDA

Pavement Management Peer Exchange Program Agenda
February 4-5, 2008 in Maplewood, MN
February 7-8, 2008 in Salt Lake City, UT

Day 1

- Welcome introduction - Host Agency 8:00

- Peer exchange program- Review agenda- Expected outcome- FHWA 8:10

- Expected outcome – All Agencies 8:20

- An Overview of the Host Agency's Pavement Management System 8:30
- Status of Pavement Management System- Participant Agencies 8:50

- Data Collection- Host Agency followed by group discussion 9:10

  Data collection activities
  Pavement condition data
  -Asphalt
  -Concrete
  Grouping
  Pavement Type (Asphalt, Jointed, Composite); Functional Class (Interstate, Arterial, Collector); Climate, etc.
  Construction and maintenance history
  Traffic data
  Optional data
  Data integration

Break 10:00

- PMS Analysis -Host Agency followed by group discussion 10:15

  Needs Assessment
  Performance Indices
  Trigger Values
  Performance modeling
  Economic analysis
  Optimization (detailed)
  Treatment decision trees

Lunch 12:00

- PMS Analysis continues 1:00

Demo by the Host Agency: Pavement Management System and its Various functions 2:00

It would be ideal to go through a simulated complete cycle – loading data to system; running needs analysis; optimization, developing candidate list of projects; adjusting projects due to schedule, political influences; what-if scenarios and forecasting conditions; graphics and reporting, etc.

- Adjournment 4:00

Day 2

Use of Pavement Management System in supporting strategic, network, and project level decisions

- Planning - Host Agency followed by group discussion 7:30

Setting investment levels
Help establish agency goals
Provide information to support the development of STIP
Provide information to support the development of long-term plans
Provide information to support HPMS requirements

- Pavement Management System as a Decision Making Tool 8:30
Host Agency followed by group discussion

Decision making Process
Communicating the message
Determining the message to be sent
Who receives the information?
What format should be used?

Break – 9:30

- Maintenance- Host Agency followed by group discussion 9:45

Links to maintenance
Who is responsible for what (PMS, Planning, Maintenance)
Support to pavement preservation programs and improve pavement performance
Pavement condition data to support a pavement preservation program
Appropriate distress for selecting preventive maintenance treatments
incorporating preventive maintenance treatments into analysis models
Treatment rules
Institutional and organizational strategies (pavement preservation engineer, regional pavement management personnel)

Lunch 11:45

- Reporting- Host Agency followed by group discussion 12:45
Feedback process

Variations in reporting depending on the users
District (Current Conditions & Treatments, Roughness Index Maps, Priority Listing)
Yearly (Past 5 Year Pavement Condition Report, Statewide Summary, Budget Analysis)
Other Reports
Access to data

PMS and Engineering and economic analysis 1:45

- Design- Host Agency followed by group discussion
Provide support for engineering and economic analyses (e.g., evaluate design effectiveness)

Break 2:15

Open Discussion 2:30

- Possible topics

- What was the implementation procedure like? Were there many modifications and customization required, such as to input and output data file formats and links to existing systems?
- Procurement of the System
- What were the vendor responsibilities, and what tasks were performed by the DOT (such as developing models, identifying treatment trigger levels)
- Is the software run only at the central office, or does each regional office use the system to develop and manage their pavement programs? Is the system used at the residency/county level? How many users? Are the MPO's involved?
- How was the experience with training and technical support from vendor? What was the training strategy and effort?
- What level and number of staff are required to operate and maintain the system (technician, administrative type, engineer, computer expert….)?
- Does the PMS include other assets? How does your PMS tie into other assets?
- After all the dust settled, does the system do what they need it to do?

Closing 3:50

Adjournment 4:00