ITD RESEARCH PROJECT RP183

AN EVALUATION OF IDAHO TRANSPORTATION DEPARTMENT NEEDS FOR MAINTENANCE MANAGEMENT AND PAVEMENT MANAGEMENT SOFTWARE TOOLS – FINAL REPORT

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16. Abstract

The Idaho Transportation Department (ITD) is facing a critical point in the maintenance and management of its highway system. The number of deficient miles is increasing, paving costs are rising exponentially, and revenue is not keeping pace with the increased costs of construction. The situation is further complicated by the fact that the Department's existing maintenance management system is no longer used due to incompatibility with the Department's recently acquired financial management system and the pavement management system is not meeting the Districts' needs.

To help address this situation, ITD initiated this research project (RP 183) to conduct an evaluation of the Department's current maintenance management and pavement management needs as the first step towards acquiring new software packages. The selected research team reviewed existing documentation and interviewed approximately 40 ITD personnel to identify critical needs. Strategies were developed for addressing the needs and recommendations for enhancements were provided. Detailed findings are presented in the final report.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
	NOTE: volumes greater than 1000 L shall be shown in m^3			
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	$candela/m^2$	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	$candela/m^2$	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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EXECUTIVE SUMMARY

Background

The Idaho Transportation Department (ITD) is facing a critical point in the maintenance and management of its highway system. The number of deficient miles is increasing, paving costs are rising exponentially, and revenue is not keeping pace with the increased costs of construction. The situation is further complicated by the fact that the Department's existing maintenance management system is no longer used due to incompatibility with the Department's recently acquired financial management system and the pavement management system is not meeting the Districts' needs to make the most cost-effective use of the available funding.

To help address this situation, ITD initiated this research project (RP 183) to conduct an evaluation of the Department's current maintenance management and pavement management needs as the first step towards acquiring new software packages. A Request for Quotations was issued in March 2008 seeking an independent research team to conduct the evaluation. The use of an outside team allowed the Department to reduce the potential for bias and to bring to the study specific expertise in maintenance management and pavement management. Applied Pavement Technology, Inc. (APTech), a pavement engineering specialty firm based in Illinois, was selected for the project. APTech provided a team with national experience in both maintenance management and pavement management, featuring extensive knowledge of the practices being used by many state highway agencies within the United States. In addition, the members of the researcher's team had no vested interest in any proprietary software packages that might be considered by the Department. As a result, the recommendations presented in this report reflect the research teams' professional opinion as to the best solutions for the Department to consider.

To better understand ITD's current capabilities and operational environment, the research team reviewed existing references describing the organization and its current structure, the features of the previous maintenance management system, the existing pavement management capabilities, and the activities that have been undertaken to enhance the existing capabilities in both maintenance management and pavement management. In addition, the research team interviewed approximately 40 ITD personnel from the central office and from each of the six Districts to identify critical needs. The project team made a significant effort to talk to all Divisions and Districts that would be impacted by the implementation of new software during a week of on-site meetings in Idaho. In addition to the meetings that took place in or around Boise, the research team traveled to Twin Falls to meet with representatives from Districts 4, 5, and 6. Some additional phone interviews were conducted later in the project to obtain information from those who were unavailable during the week of June 9th when the research team was in Boise.

The information from the interviews was used to identify needs and gaps in existing capabilities. Strategies for addressing the gaps were developed and recommendations for enhancements were provided. In developing the recommendations, the research team assumed the new maintenance management and pavement management systems would interface successfully with ITD's financial management and geographic information systems to maximize the return on its investment.

As a basis for comparison, phone interviews with representatives from other state highway agencies that had recently implemented new maintenance management and/or pavement

management software were conducted and any available documentation (such as system specifications or requests for proposals) were obtained. Detailed findings from this study are presented in the final report. A more concise summary of the findings and recommendations are presented in the remainder of this Executive Summary.

Findings

The research team reached the following key findings in terms of maintenance management and pavement management needs.

- **Since the implementation of the Advantage Financial Management System in 2005, ITD has not had a functioning computerized maintenance management system to track maintenance activities.** Until 2005, ITD used a maintenance management system (MMS) that reported maintenance accomplishments and costs and provided historical comparisons of productivity rates. Since the system was not compatible with the new financial management system, it stopped being supported and is no longer used. The information that was previously available in the MMS is missed by District Maintenance personnel because the current manual process of recording information in diaries makes the information difficult to retrieve and report. The lack of such information makes it difficult for the Department to describe the impact of budget changes on network conditions. The acquisition of new maintenance management tools is considered a high priority throughout the Department and there is a need to expand the capabilities of the program to allow more planning of maintenance activities.
- **The method of entering maintenance activity information (including resources used, activity type, and location) should be compatible with the new Financial Management System**. The Financial Management System (Advantage) uses timesheets to record labor expenditures, but the timesheets do not allow maintenance activity information to be linked to location. Ideally, all of this information is entered directly into the MMS with payroll information transferred to the Financial Management System for processing. The old MMS relied on timesheets to record the information needed. This process created a good incentive for field personnel to enter maintenance activity details since the information was required for them to be paid. However, for this process to work with the new MMS software, there are a number of issues that need to be addressed. For instance, human resource (HR) checks that are currently performed in real time as timesheets are being entered (such as employee status verification, availability of benefits, and so on) are required without delaying the processing of timesheets (which occurs every two weeks). Electronic signatures by the employee and the supervisor are also required when timesheets are entered. It is considered too expensive to modify Advantage at this point in time. Therefore, an alternate approach to linking payroll information to maintenance activities and locations is desired. The resulting solution should address the HR requirements, and easily adapt to any changes that are made to the payroll process by the controller to facilitate payroll processing. These changes are reportedly made on a regular basis.
- **Previous work in defining Levels of Service can serve as the baseline for developing performance-based budgeting capabilities.** In addition to reporting productivity information, today's MMS can assist with maintenance planning by estimating budget requirements to meet targeted condition levels and by providing performance measurement tools. To develop reasonable budget estimates to achieve a targeted condition level, and to be able to determine how good a job is being done for the money

expended, an agency should have a method of estimating current conditions. For maintenance and operations activities, this is normally expressed in terms of Level of Service (LOS). A method of defining LOS was developed previously as part of a study conducted by Cambridge Systematics in December 2005. The tool, referred to as Performance Reporting in Maintenance Operations (PRIMO), was designed to assist in performance-based budgeting but the tool and the associated LOS definitions were never adopted (although some performance measures have been implemented for rest areas). However, the LOS ratings that were developed to support PRIMO for most assets reflect the state-of-the-practice and are sufficient as a first step in this process. The Department still needs to establish a formal Condition Assessment Program so this information is collected consistently across the state on a regular basis.

- **Because the Department's pavement management system does not fully address the needs of District personnel, one District has initiated a pilot project to demonstrate the capabilities of an alternate system.** The Transportation Planning Division has developed the Department's pavement management system to provide an assessment of pavement needs determined from annual pavement condition surveys. Needs are defined in terms of deficient pavements, which are identified when the results of the pavement condition surveys indicate that pavement conditions are below a certain level. The percentage of pavements that are considered to be deficient are reported regularly to the legislature and every other year to the FHWA, and District Engineers are evaluated (in part) on the percentage of deficient miles in their District. Therefore, the selection of projects is oriented towards reducing or eliminating the number of miles of deficient pavement. Interviews with ITD Management indicate that they plan to continue reporting deficient miles to the legislature because the measure is understandable and useful to the legislature.

  The analysis used by ITD's Transportation Planning Division, which focuses on addressing deficient pavements (a *worst first strategy*), may lead to worse long-term conditions than an alternate strategy that includes some preventive maintenance to keep pavements in good condition longer. Most of the District personnel reported that they want to utilize preventive maintenance treatments but since these types of projects do not eliminate reported deficiencies, there is little incentive to do so. The current software has limited ability to forecast future conditions and to evaluate alternate treatment strategies that focus more attention on preservation strategies.

  In the absence of both analysis tools and information from the Transportation Planning Division that would evaluate the trade-offs between different treatment strategies, District 6 worked with a contractor to develop and implement a customized version of CarteGraph's pavement management software, PavementView Plus, as a pilot project. The PavementView Plus software is capable of analyzing the impacts of different treatment strategies over a multi-year period. It includes pavement performance models that predict the change in pavement conditions over time and treatment rules that define the conditions that should exist for different types of treatments to be used. For instance, treatment rules could be defined that permit chip seals to be considered on a low-volume facility but not on a high-volume facility. By establishing multiple sets of treatment rules, different strategies can be evaluated. In other words, one set of treatments could include projects to address deficient projects and another set could include a combination of preservation, restoration, and reconstruction alternatives. The pavement management system can analyze the predicted conditions for each set of treatments at the same funding level and determine which strategy results in the best network conditions five or

ten years into the future. The software can also help determine the combination of projects (and treatments) that make the most cost-effective use of available funds. There are pavement management systems available commercially that provide more flexibility than the PavementView Plus software (in terms of the number of condition indices that can be used and the variables that can be used to develop performance models and treatment rules). This additional flexibility is needed if the program were to be used at the Statewide level, given the diverse characteristics of pavements across the State. The software reportedly satisfies the needs of the District 6 staff for programming projects and allows them to demonstrate the consequences of various expenditures.

- **Pavement-related information is not easily accessible by District personnel for use in selecting projects and designing treatments**. Discussions with ITD personnel indicate that there are issues with data accessibility that limit the usefulness of the existing pavement management information. For example, the summary results from the pavement condition surveys reported to the Division of Highways are not sufficient for treatment selection. Additionally, by the time Needs Reports are published, the information is dated, limiting its value to District personnel. Better, more timely access to the detailed information that is currently collected on distress type (i.e. crack type), severity, and quantities is needed in addition to the calculated indexes. Further, because the current equipment used to assess road condition does not provide reliable rut data, this information is not used in determining pavement needs. The Transportation Planning Division is purchasing a new van that will substantially improve the quality of rut data. In addition to the pavement distress information, Division of Highways personnel need access to construction histories and geometric data, such as roadway width and shoulder information to determine whether lane and shoulder widths are adequate prior to repair. This information is available by requesting the information from the Transportation Planning Division, but Division of Highway personnel would prefer being able run queries to obtain the information themselves. The results of nondestructive deflection testing, which are used in pavement overlay thickness design, are currently stored in project report files. This means that the information is not easily accessible by others and it is difficult to track historical trends. Having a central data repository for storing this information would improve District access to this information.

Recommendations

The final report documents several options for addressing the Department's maintenance management and pavement management needs. These options range in the degree to which they satisfy the specific needs documented in the report, but recognize that the amount of available funding to address these issues is limited. The key recommendations provided in the final report are included here. A general assessment of the potential return on investment associated with the implementation of these recommendations is provided in the next section of the Executive Summary.

1. Implement New Maintenance Management Software

The research team concluded that the Department's highest priority is implementing new maintenance management software that has the basic functionality that was available in the Department's previous MMS plus expanded capabilities for performance-based budgeting activities. It is recommended ITD first utilize the basic cost-accounting features of the software, which will allow the Department to schedule work crews, manage equipment and/or materials, track costs and productivity rates, plan future resource requirements, and report statistics using

standard or customized reports. These features require an investment in new software and the development of an interface between the MMS and the Advantage Financial Management System to record time, material and equipment resource usage, and location in a way that satisfies the needs of both groups. Several options are available for establishing the interface. One option is for personnel information to be passed to the new MMS (as the Louisiana Department of Transportation and Development is doing). Alternatively, a separate interface is developed for entering resource information (as the Kansas DOT is developing). Regardless of the approach selected, it is critical that:

- Human resource checks are performed in real time (or on a daily basis).
- Time, material, and equipment details can be linked to maintenance activity type and location.
- Maintenance personnel only have to enter the information once.

The cost of this basic option is estimated at $2.7M, as shown in table ES-1. This option includes a statewide license for the MMS software, the development of a customized interface with the Advantage program for payroll, several handheld data collection devices with GPS functionality in each District (approximately 8 to 10 units in each District to share among crews), and support services to customize the software and to conduct training. Annual maintenance costs associated with the statewide license are estimated at $300,000.

Table ES-1. Costs associated with the recommended **basic MMS option**.

Activity	Estimated Cost	Comments
Statewide software license and implementation	$1,500,000	These costs include software licenses and the cost of developing interfaces to existing data sources, with the exception of the financial management system
Financial management system interface development	$500,000	These costs assume a fully-customized interface will be developed for ITD between Advantage and its new MMS
Hardware	$300,000	These costs provide funding to acquire approximately 8 to 10 portable GPS units for each District to share among maintenance crews and vehicles (for reporting activity location)
Customization	$250,000	Within the software, there are opportunities to customize user interfaces to meet the needs of the agency
Training	$150,000	Utah DOT used its vendor to conduct train-the-trainer sessions so most training of field personnel is done internally
Total - One-Time Cost	***$2,700,000***	
Annual maintenance	$300,000	Utah DOT reports that annual maintenance costs are approximately 20 percent of the cost of software licenses

In several years, after the basic MMS capabilities are in place, the same software can be used to provide additional maintenance management budgeting features. In addition to providing the cost-accounting functions that will allow the Department to perform historical cost comparisons and to evaluate productivity rates, the software will also have the functionality to conduct performance-based budgeting activities. This type of analysis relies on the availability of an assessment of maintenance quality through a Maintenance Quality Assurance program. These types of programs use agency-established condition thresholds to represent different levels of service (LOS) for each class of asset. The condition information is obtained during a field inspection of the assets contained in a representative number of samples in each District. In most agencies, these surveys are conducted by District personnel, although research is being done nationally to determine the amount of information that can be obtained using automated methods. Using the criteria established by the agency, a LOS can be calculated by District, region, shed, foreman, or geographical area. Alternatively, the LOS can be reported on a statewide basis. Once the current LOS is established, a targeted LOS can be set and the funding necessary to meet the targeted LOS can be determined.

ITD previously invested in the development of LOS definitions for many of its maintenance assets. These definitions can serve as the basis for developing performance-based budgeting tools. Therefore, the research team further recommends that ITD plan to develop a formal Maintenance Quality Assurance Plan (to collect the condition information) and to access feature inventories for key assets (such as pavements, signs, bridges, drainage features, and guardrails). These additional capabilities, which are NOT recommended at this time but should be considered once the basic MMS is implemented, can be provided at a cost of approximately $1.05M (as documented in table 10 in the final report). Not included in the cost estimate, but recommended to ITD is the eventual addition of GPS units in each maintenance vehicle so all maintenance activities can be entered geo-spatially. These could be added at a cost of approximately $3,000 to $5,000 per unit as vehicles in the fleet are replaced.

Alternate MMS Strategies

Because of significant decreases in available highway funding and the corresponding increases in the cost of construction materials, state transportation agencies are significantly limited in their ability to invest in new programs such as the ones recommended in this report. Recognizing that these limitations exist, the research team considered alternate strategies that might reduce the resource requirements while still providing some of the basic functionality recommended.

Since restoring the basic functionality of the MMS is the highest priority identified during this study, it is very important that ITD invest in MMS software to store and retrieve information about maintenance activities, resources used, and activity location. Ideally, an interface is developed between the new MMS software and the Advantage financial management system, but the interface could be postponed by entering information separately into each system. This approach requires duplicate data entry into two different systems, which is not ideal, but satisfies the need to report maintenance costs, estimate productivity, and perform basic budgeting activities. A summary of the strategies that could be utilized to reduce the cost of the MMS implementation from $2.7M to approximately $900k to $1,250k is provided.

- Postpone the development of the interface with the financial management system (Advantage). This will likely result in duplicate data entry that will have to be carefully managed to limit data entry errors.

- Acquire only the most basic modules of the MMS to reduce licensing costs. Consider subscribing to a MMS (rather than licensing the software) if that option is available. Some vendors offer this option at approximately 1/3 the cost of an individual license.

- Rather than use a consultant for the implementation, savings of approximately 25 percent of the consulting fees can be realized by doing most of the implementation work in-house under the direction of the vendor's project manager. Additional savings could be realized by having in-house staff conduct some of the training.

- Postpone the purchase of the handheld GPS units.

To see how the changes identified in this section would reduce cost for acquiring an MMS, see table ES-2.

Table ES-2. Options to Reduce Cost of MMS Implementation.

Activity	Estimated Cost	Comments
Basic MMS Cost Estimate	***$2,700,000***	
- Financial Management System Integration	($500,000 in potential savings)	Eliminate/postpone MMS integration with ITD's financial management system
- Optional System modules	($400,000 to $700,000 in potential savings)	Only acquire most basic modules or subscribe to service rather than purchase MMS
- Consultant Services and Training	($250,000 - $300,000 in potential savings)	Rely on in-house staff to implement system instead of consultants
- GPS	($300,000 in potential savings)	Postpone purchase of handheld GPS units
Reduced Initial Investment	***$900,000 - $1,250,000***	

The research team does NOT recommend that cost savings be realized through the implementation of a less functional software program. Although these programs may cost less initially, they are frequently limited in their ability to offer improved functionality over time. In recent years there have been two state highway agencies that selected low-cost systems through their procurement process. One of the contracts was cancelled after the first phase was completed and the second is behind schedule because the selected software is not meeting the State's needs. These examples illustrate that sometimes short-term cost savings can lead to much higher costs in the long run.

2. Implement New Pavement Management Software

The research team also recommends that new pavement management software be implemented to enable the Department to better analyze alternate treatment strategies. The current pavement management system satisfies a number of network-level planning needs, but does not provide all

the information Districts need to make the most cost-effective use of their available budgets. To address their needs, pavement management software that can compare the long-term conditions associated with several alternate treatment strategies (including preventive maintenance strategies) is needed. These programs are available commercially and are estimated to cost approximately $950k plus the cost of annual maintenance fees of approximately $50k. These costs are presented in table ES-3.

Table ES-3. Costs associated with the recommendation to implement **new basic pavement management software**.

Activity	Estimated Cost
Software	$700,000
Customization and training	$250,000
Total – One Time Cost	***$950,000***
Annual licenses	$50,000

This recommendation does NOT mean to imply that the Department should abandon its current method of calculating needs. This information is still important for planning purposes and the legislature understands it and finds value in the data. However, it is not adequate for project and treatment selection because it only identifies roads in *Poor* and *Very Poor* condition. The Districts' desired outcome of programming preservation, restoration, and reconstruction projects better reflects the pavement preservation strategy being promoted nationally by the Federal Highway Administration.

The research team recommended several other changes to better support the functionality of the pavement management system. First is the recommendation to develop a distributed database structure that enables separate databases to be linked together transparently so that anyone logged into the system has access to the content of any of the databases. This will enable the Districts to access pavement-related information, such as the results of nondestructive deflection or skid testing, during treatment selection and design. Without this database structure, the new pavement management system becomes the repository for pavement-related information so the Districts and HQ will both need copies of the pavement management software. The second recommendation is to enhance the Department's Geographic Information System (GIS) by changing it from a one-directional map display (in which both directions of a divided highway are represented by a single line) to a two-directional display (in which each direction of a divided highway is represented by its own line). This feature allows the Department to better display maintenance activities or test results that differ by direction. Neither of these changes is mandatory, but both will enhance the functionality of the Department's new pavement management software. The estimated costs associated with these additional activities are summarized in table ES-4. These estimates are less precise than the other estimates because the specifications required fall outside the scope of this project and will likely be conducted as Information Technology (IT) projects.

Table ES-4. Additional recommendations and costs to enhance the functionality of the **new basic pavement management software**.

Activity	Estimated Cost	Comments
GIS improvements and LRS issues	$500,000 - $1,000,000	The research team's scope concentrated on MMS and PMS needs; however both systems would benefit from addressing these improvements as described elsewhere in the report. These include modifying the GIS to be two-directional and eliminating the inconsistencies in the distance measurements with the video log van.
Centralized data warehouse	$1,000,000 - $3,000,000	Developing a centrally-distributed database is a Department-wide activity that is beyond the scope of this project. However, the availability of this feature would be very beneficial to the Districts so they can have real-time access to pavement-related information to assist with project and treatment decisions and in pavement design.
Consulting services and training	$200,000	Some training would be required for collecting, storing, querying, and reporting data.
Total - One-Time Cost	***$1.7 – $4.2M***	

Alternate PMS Strategies

An evaluation of alternate strategies was conducted to determine whether a lower cost strategy is available to enhance the pavement management analysis capabilities within ITD. Since ITD's current pavement management system provides most of the functionality needed for planning purposes, the low-cost strategy focuses on providing Districts with the ability to evaluate alternate treatment strategies using software similar to what is being used in District 6. This strategy provides for each District to obtain a copy of the PavementView Plus pavement management software to evaluate treatment options within their geographic area. District 6 estimates that they have invested approximately $100k in their pavement management capabilities to date. Building on the lessons learned through their implementation, and recognizing that there may need to be some adjustments to the performance models and treatment rules in each District, it is estimated that a similar program could be implemented for approximately $80,000 per District ($400,000 total since District 6 already has a system in place). Training could be performed, in part, by District 6 personnel who are familiar with the operation of the software. A disadvantage to this approach is that it does not provide a means of running a statewide analysis that illustrates the long-term consequences of various scenarios. For the statewide analysis, a more robust system, such as the one included in the original recommendations is required. Selection of this alternate option could also have even larger negative impacts on statewide planning capabilities due to potential losses in the value and availability of data and the current level of understanding with the legislature.

Additionally, the Department should modify its business processes to support the use of more preventive maintenance treatments that defer the need for more expensive rehabilitation treatments. The current system, which focuses on reducing existing deficiencies, is expected to lead to worse long-term conditions than a pavement preservation strategy that includes both

preventive maintenance and pavement rehabilitation treatments. The availability of software tools that can evaluate the consequences of these types of programs is also important to the success of a pavement preservation philosophy.

Return on Investment

The recommendations included in this report represent a significant investment of ITD resources. However, in exchange for the investment, the agency can expect to realize numerous benefits, such as those listed below from the American Association of State Highway and Transportation Officials (AASHTO) in its *Pavement Management Guide* (2001).

- More efficient use of available resources.
- The ability to justify and secure more funding for pavement maintenance and rehabilitation.
- More accurate and accessible information on the roadway system.
- The ability to show the impact of funding decisions.
- The selection of more effective maintenance and rehabilitation strategies.
- Improved communication between stakeholders both within and external to the organization.
- The ability to better answer questions from management, elected officials, and the public.
- Improved creditability when dealing with management, elected officials, and the public.

To date, it has been difficult to quantify these benefits in monetary terms that allow an agency to determine its return on the system investment. No quantitative information on the benefits associated with the implementation and use of a MMS is available in the literature, but the *Guidelines for Maintenance Management Systems* lists the following subjective benefits (AASHTO 2005):

- Maintenance quality rating systems help define asset conditions in customer-oriented terms.
- With limited budgets, managers can decide between competing needs.
- A MMS can help link customer expectations with desired outcomes and results.
- A MMS can link desired outcomes to resource and budget needs.
- Managers can assess the consequences of shifting funds between competing program objectives.

Several research studies have documented the benefits associated with the use of pavement management systems and the more cost-effective treatment strategies recommended. One study, which is based on an analysis of the costs and benefits realized by the Arizona DOT, shows a $30 savings in pavement expenditures for every dollar spent on the development, implementation, and operation of a pavement management system (Hudson et al. 2000). The cost savings were realized by the agency's selection of more preventive treatment strategies, as recommended by the pavement management system, rather than waiting until pavements were badly deteriorated. The availability of models to forecast deterioration and treatment performance was also noted as a factor in the cost savings.

Another way of looking at the return on investment is through a benefit cost analysis that compares the benefits associated with the use of pavement management to the costs associated with the implementation and operation of the system. A benefit cost analysis conducted on data from the Ministry of Transportation in Alberta, Canada shows a ratio of 100 to 1 due to the improvements in serviceability associated with the use of pavement management (Hudson and Haas 1994). A similar analysis for the Arizona DOT system showed a benefit to cost ratio of 14 to 1 within the first year of the pavement management implementation, even when only agency costs and benefits are considered. If user benefits and costs had been considered, the ratio would have been considerably higher (Cowe Falls et al. 1994).

These studies indicate that an investment of $5M in management systems could lead to $150M in savings in rehabilitation needs through the use of more cost-effective pavement preservation strategies that extend pavement life at a relatively low cost. Further, these studies demonstrate that even if only a portion of the benefits can be attributed to the use of management systems, the benefits realized far outweigh the associated implementation and operational costs. Assuming similar ratios could be realized by ITD, the recommended investment level of $2.7M for MMS and $0.95M for PMS could lead to almost $110M in savings through the use of a more cost-effective program (a benefit to cost ratio of approximately 30 to 1). Using the more conservative benefit to cost ratio determined for the Arizona DOT (a 14 to 1 ratio) will still result in savings estimated to be greater than $50M.

Closing

The research team notes that the Idaho Transportation Department is fortunate to have personnel who are committed to the enhancement and improvement of its practices and policies. The ITD personnel who participated in this study were generous with their time and forthright in describing their needs. There is strong support for the implementation of a new MMS among Department personnel and strong backing for the statewide use of cost-effective pavement preservation strategies. The enthusiasm and support for these programs are important ingredients to the overall success of the maintenance and pavement management enhancements selected by the agency.

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CHAPTER 1.0 – BACKGROUND

The Idaho Transportation Department (ITD) is facing a critical point in the maintenance and management of its highway system. The number of deficient miles is increasing, paving costs are rising exponentially, and revenue is not keeping pace with the increased costs of construction. The situation is further complicated by the fact that the Department's existing maintenance management system is no longer used due to incompatibility with the Department's recently acquired financial management system and the pavement management system is not meeting current demands.

To help address this situation, ITD initiated this research project (RP 183) to conduct an evaluation of the Department's current maintenance management and pavement management needs as a first step towards acquiring new software packages. A Request for Quotations was issued in March 2008 seeking an independent research team to conduct the evaluation. The use of an outside team allowed the Department to reduce the potential for bias and to bring to the study specific expertise in maintenance management and pavement management. Applied Pavement Technology, Inc. (APTech), a pavement engineering specialty firm based in Illinois, was selected for the project. APTech provided a team with national experience in both maintenance management and pavement management, featuring extensive knowledge of the practices being used by many state highway agencies within the United States. In addition, the members of the researcher's team had no vested interest in any proprietary software packages that might be considered by the Department. As a result, the recommendations presented in this report reflect the research teams' professional opinion as to the best solutions for the Department to consider.

To better understand ITD's current capabilities and operational environment, the research team reviewed existing references describing the organization and its current structure, the features of the previous maintenance management system, the existing pavement management capabilities, and the activities that have been undertaken to enhance the existing capabilities in both maintenance management and pavement management. In addition, the research team interviewed approximately 40 ITD personnel from the central office and from each of the six Districts to identify critical needs. The project team made a significant effort to talk to all Divisions and Districts that would be impacted by the implementation of new software during a week of on-site meetings in Idaho. In addition to the meetings that took place in or around Boise, the research team traveled to Twin Falls to meet with representatives from District 4, 5 and 6. Some additional phone interviews were conducted later in the project to obtain information from those who were unavailable during the week of June 9th when the research team was in Boise.

The results of the interviews were used to define the Department's needs and to identify any gaps between its current capabilities and the desired features. The results of this analysis are presented in Chapter 2 for Maintenance Management and Chapter 3 for Pavement Management.

In addition to studying ITD's practices, the research team interviewed representatives from several other state highway agencies (SHAs) that had recently initiated changes to their maintenance management systems or implemented new pavement management software. The information obtained from these agencies is included in Chapter 4, which highlights current practices around the country. This information is provided to offer a frame of reference for the recommendations made by the research team.

The information obtained during the interviews, the input provided by other state highway agencies, and the experience of the research team all factored into the development of implementation strategies that might be considered by ITD to enhance its maintenance management and pavement management capabilities. Chapter 5 presents implementation options for the Department to consider. The options for both maintenance management and pavement management range in complexity and cost so the Department can better match its plans to fit within resource constraints. In Chapter 6, the research team presents its recommendations for moving forward. A key assumption used by the research team was that any new management systems would interface successfully with the existing financial management system (Advantage) and the Geographic Information System to increase the potential return on investment.

In addition, several appendices are provided. Appendix A includes a summary of a survey of maintenance management practices in SHAs. Appendix B, C, and D include samples of recent Requests for Proposals (RFP) from state highway agencies that had recently acquired new software. The technical specifications from the Mississippi DOT RFP are included in Appendix B, the entire RFP issued by the Utah DOT is included in Appendix C, and the RFIs issued by the Alabama DOT and New Mexico DOT are included in Appendix D. These latter two documents are combined because they are so much shorter than the Mississippi and Utah RFPs. Appendix E contains a recently-released RFP for pavement management software that was issued by the Virginia DOT.

CHAPTER 2.0 – MAINTENANCE MANAGEMENT NEEDS ASSESSMENT AND GAP ANALYSIS

An important part of this research project involved interviewing ITD representatives to identify existing capabilities and to determine additional capabilities desired for both maintenance management and pavement management activities. Based on the interview discussions, the information contained in the background references, and the research team's knowledge of current practice, maintenance management and pavement management needs within the following four areas were identified:

- Data needs.
- Information and reporting needs.
- Analytical functionality.
- Interfaces with existing systems.

A summary table is provided at the end of each section that identifies the degree to which each need is currently addressed, its relative importance to the Department, and the type of change required to eliminate the gap (i.e., process change, software feature, or some other type of change). Maintenance management needs are presented first since interviewees placed a higher priority on maintenance management than pavement management, largely due to the fact that there are currently no tools in place to justify maintenance expenditures or to analyze productivity rates. The availability of pavement management information, while not currently addressing all the needs within the Department, satisfies the Department's network-level planning requirements.

Identified Maintenance Management System Needs

Until 2005, ITD used a maintenance management system (MMS) that reported maintenance accomplishments and costs and provided historical comparisons of productivity rates. Since the system was not compatible with the new financial management system, it stopped being supported and is no longer used. The information that was previously available in the MMS is missed by District Maintenance personnel because the current manual process of recording information in diaries makes the information difficult to search and report. The lack of such information makes it difficult for the Department to describe the impact of budget changes on network conditions. The acquisition of new maintenance management tools is considered a high priority throughout the Department and there is a need to expand the capabilities of the program to allow more planning of maintenance activities.

Data Needs

- ***Provide a single point of entry for data interfaces***. It is important to avoid duplicate entry of data within different systems. The importance of this issue was specifically referencing the interface with the financial management system but it is important for any type of data needed to support a management system. Data entry should be as simple as possible and it should make use of available technology as much as possible. Access from remote locations will also be an important issue to address since some sheds do not have high-speed internet connections. The Department will also have to develop processes to ensure that if automated data recorders on trucks are reporting information, the same information

isn't also being reported by work crews. For instance, if Global Positioning Systems (GPS) are installed in maintenance vehicles to automatically identify field locations, field crews should not be required to manually enter field locations. Maintenance personnel reported that only three Districts currently have onboard systems available for winter maintenance activities, so fully utilizing technology requires a capital investment. In the previous MMS, time, location, and activity information were captured on timesheets.

- ***Provide compatibility with the new Financial Management System***. The timesheet entry should be compatible with the Financial Management System (Advantage). There are a number of issues that need to be addressed for this to occur. For instance, human resource (HR) checks that are currently performed in real time as timesheets are being entered (such as employee status verification, availability of benefits, and so on) are required without delaying the processing of timesheets (which occurs every two weeks). Electronic signatures by the employee and the supervisor are also required when timesheets are entered. The old MMS did not have real time edits and so information was corrected offline. As a result, different values were reported at times and corrections were not always timely. Because of these inconsistencies, people lost confidence in the data.

  The previous system required that information needed by both the MMS and the financial management system was entered through timesheets. This process created a good incentive for field personnel to enter the information since the information was required for them to be paid. However, when Advantage was implemented the new timesheets no longer required that maintenance activity and location be reported since that information is not needed for payroll activities. It is considered too expensive to modify Advantage at this point in time. Therefore an alternate approach to linking payroll information to maintenance activities and locations is desired. The resulting solution should address the HR requirements, but also should easily adapt to any changes that are made to the payroll process by the controller to facilitate payroll processing. These changes are reportedly made on a regular basis.

- ***Establish feature inventories***. There are some feature inventories in place, but not for all roadway assets. Information on some features, such as guardrail and culverts, may be in various forms of Excel spreadsheets, and other feature inventories (such as pavements, bridges, and signs) are maintained in databases outside Maintenance. There was interest in including the buildings, maintenance yards, and stockpiles in the inventory. Inventory information is critical for budgeting activities since it is important to know how many features should be maintained. Establishing the features inventory is one of the most time-consuming activities required to establish a new MMS. Therefore, some agencies start by inventorying their most important assets or the most expensive assets to maintain. The remainder of the inventory is established over time.

- ***Develop a method of assessing feature condition***. To develop reasonable budget estimates to achieve a targeted condition level, and to be able to determine how good a job is being done for the money expended, an agency should have a method of estimating current conditions. For maintenance and operations activities, this is normally expressed in terms of Level of Service (LOS). A method of defining LOS was developed previously as part of a study conducted by Cambridge Systematics in December 2005. The tool, referred to as Performance Reporting in Maintenance Operations (PRIMO), was designed to assist in performance-based budgeting but the tool and the associated LOS definitions were never adopted (although some performance measures have been implemented for rest areas). However, the LOS ratings that were developed to support PRIMO for most

assets reflect the state-of-the-practice and are sufficient as a first step in this process. The Department needs to establish a formal Condition Assessment Program so this information is collected on a regular basis using statistical sampling and condition is reported consistently across the State.

- ***Display information using Geographic Information Systems (GIS)***. Graphical displays of information are an easy way to quickly visualize maintenance needs. The added advantage to presenting maintenance needs in this manner is that long and short sections can be identified quickly. However, the current linear referencing system has reportedly caused some confusion, especially when work activities have to be reported in terms of multiple segment codes. Also, since the GIS has been established in only one direction, it limits its applicability for displaying maintenance activities. Changing the GIS to be two-directional is preferred to better display maintenance activities.
- ***Link the MMS to the video log***. By linking these two systems, users will be able to view the conditions at sites where extensive maintenance resources are being expended. In order for the new MMS to be linked to the video log, the linear referencing issues discussed under the previous bullet need to be addressed since the video log uses segment codes.
- ***Provide interfaces with other sources of information***. In addition to being able to interface with the Financial Management Package, it is important that the MMS be able to interface with the Idaho State Police (to identify slideouts), the Department's crash database, wildlife migration patterns, and with Statewide Communications. The Department's Equipment Management System should also be linked to the MMS to assist with equipment scheduling activities. Additionally, the system should link to the independent databases created for signs and those needed to be created for striping and guardrails. This requires that the data structure and data dictionary be provided with the new MMS so that these, and any future interfaces, can be developed.
- ***Ensure data quality***. The importance of data quality can not be underestimated. Therefore, processes should be established to minimize and prevent data input errors and to verify data entered into the system. Some process should be incorporated into the data entry process (so only valid data can be entered), but most aspects of quality rely on the individual entering the data. Training on the importance of the data being entered, in addition to the procedural aspects of the MMS, is an important step towards data quality.
- ***Ensure that feature and cost information is available electronically***. At a minimum, District personnel would like to be able to identify activity type, location, names of personnel involved, amount of time spent, amount and type of material used, and amount and type of equipment used. This information would be linked to cost records to determine the total cost associated with various activities.
- ***Use actual cost data in reporting***. In the past, average rates were used for labor, equipment, and material costs. In the new MMS, users expressed interest in using actual rates through links with financial and payroll data. Since the old MMS used average cost numbers for charge rates and for some material and equipment costs, this would improve the accuracy of the information being reported and would allow geographic cost differences to be taken into consideration.
- ***Capture both contract maintenance work and work conducted by state forces***. Both types of information are required to adequately reflect maintenance costs.

- ***Develop a process for tracking maintenance functions performed by inmate labor***. In the old MMS, any work performed by inmate labor had to be manually entered into the system as a separate process since inmates are not paid using ITD labor codes (and so cost information wasn't entered through timesheets). Since inmate labor is still being used, a process should be developed to incorporate this information into the new MMS.
- ***Capture the information currently being entered into the daily maintenance diary***. The information contained in the diary is currently being recorded manually. This makes it difficult to retrieve and report information. For example, it would be difficult to determine the last time a feature was worked on or to analyze how frequently certain activities are being performed. It would be more efficient to enter the information into a computer in the truck and have the data uploaded when the computer is placed in a docking station (back at the shed) so it is available immediately for reporting purposes.

Information and Reporting Needs

- ***Report basic cost accounting information***. It is important to be able to account for equipment, material, and labor usage in the new MMS and report what has been accomplished, when it was done, where it was performed, and what resources were used. At a minimum, it is important to report all primary maintenance activities such as tracking salt and chemical usage, plant mix, plow days, ditching operations, mowing, and weed spraying. This information will allow Maintenance to account for how its money is being spent and will also allow District personnel to identify areas with recurring maintenance problems.
- ***Provide historical work history activities***. If the Department moves forward with adopting a program that reports the LOS provided for various activities, it will allow Maintenance personnel to quickly identify assets that are being maintained below the desired LOS. To help schedule work activities, District personnel would like access to historical data that indicate how long it has been since maintenance has been performed on each asset. For example, they would like to be able to pull up reports that include the last time a particular culvert was cleaned or when a bridge (or sign structure) last received maintenance. This will also help the Department respond to tort liabilities. Since there has been a significant amount of time that has passed since maintenance activities have been captured electronically, and because of questions concerning the quality of the data in the old MMS, the historical reporting is expected to start from the point at which the new MMS is implemented.
- ***Provide transparent access to data***. To meet the needs of most District personnel, it is important that the MMS database structure is transparent. In addition to being able to use the information for planning and scheduling maintenance activities, District offices want to be able to write their own queries so they can validate the data and build confidence in the system. Additionally, they see the opportunity to write their own applications or link new systems if access to the data is transparent.
- ***Provide access to all potential users***. It is estimated that hundreds of Highway Division personnel will need access to portions of the MMS, including most District personnel. For some, the access will be limited to data entry, reporting, and queries. However, there are also expected to be personnel from each District who will run scenarios and will use the system for more sophisticated types of analyses.

- ***Summarize costs associated with disaster and damage recovery***. This information will be used by Budget and Finance to request reimbursement from the Federal Emergency Management Agency (FEMA), insurance companies, or other sources.
- ***Provide the ability to import and export data***. It is important that information from the MMS can be imported or exported to other systems both within ITD and outside ITD.
- ***Calculate total projects costs***. Some maintenance activities may be comprised of multiple activities. Therefore, the MMS will need to be able to calculate total costs by summarizing the costs associated with all related activities.
- ***Report costs at virtually any sublevel***. It is possible that reports will be needed at the headquarters, District, region, foreman, or shed levels. Statewide reports will also be needed.
- ***Provide information needed for GASB-34 reporting***. Information on maintenance activities and the dates these projects are completed is required. Therefore, a process needs to be developed so this information is available for GASB-34 reporting. Consistent use of treatment coding between systems is also required to limit the amount of manual manipulation of the data by those responsible for the GASB-34 reporting.
- ***Consider reporting information in a dashboard format***. Some agencies are using dashboard displays as a way of presenting information used by managers on a regular basis. A dashboard displays pre-selected graphics automatically each time the user logs onto the system. An example is included as figure 4 in Chapter 4. This approach simplifies the comparison of current information to targets (or historical condition) without requiring reports to be run.

Analytical Functionality

- ***Analyze productivity rates***. It is important to track productivity rates at all levels within the Department. This can be performed as long as basic cost accounting tools are available with costs tracked by treatment and location. As noted earlier, actual costs rather than average costs should be used.
- ***Provide planning and budgeting tools***. There is interest in building on the cost accounting functions of the old MMS so the information can be used to monitor the level of service provided for various roadway assets and to establish targeted levels of service. In addition, maintenance personnel want to be able to use the information to perform budgeting and scheduling activities. This information will allow the Department to estimate the budget required to provide different levels of service, for example.
- ***Address the types of analyses desired at the Headquarters level***. At this level, there is interest in performing the following types of analyses:
  - Calculating differences in the cost or production rates for a particular activity by District or geographic region.
  - Determining whether it would be more cost-effective to contract work out rather than perform it using in-house crews.
  - Forecasting future needs based on past performance or changes in funding.
  - Determining the return on the investment being made.
  - Estimating costs required to raise the LOS for a particular asset or multiple assets.

  - Estimating the resources required to maintain new facilities added to the system.

- ***Address the types of analyses desired at the District level***. At this level, there is interest in performing the following types of analyses:
  - Determining what work is being accomplished for the money spent.
  - Evaluating changes in work crew efficiencies to determine where adjustments are needed.
  - Planning and scheduling maintenance activities.
  - Comparing current work levels and costs with prior years' historical values (once histories are established).
  - Demonstrating the needs for additional money.
  - Tracking materials used at different points of the year.
  - Determining when adjustments are needed to meet the budget.

Interfaces with Existing Systems

- ***Develop client-distributed database features***. The MMS should interface with a significant number of databases and other data sources (such as Excel files) to operate. Since it is not realistic to expect all information to be stored in the MMS (since some data are owned by others), a client-distributed database structure is recommended. This type of structure allows source data to be used by the MMS even though it may be stored outside the MMS. Data unique to the MMS will be stored directly in the new system. The distributed nature of the database is hidden from users.
- ***Develop both internal and external data interfaces***. Throughout the meetings, a number of desired interfaces were discussed, including the following:
  - Financial Management System (Advantage).
  - Idaho State Police (slideouts).
  - Safety (crashes).
  - Environment (wildlife migration patterns).
  - Equipment Management System.
  - Pavement Management System.
  - Materials (results of skid testing and nondestructive deflection testing).
  - Existing Asset Inventory Databases (signs, bridges, guardrails, striping, culverts, buildings, lights, maintenance yards, stockpiles).
  - Project Tracking Database and/or Contract Administration (for contract maintenance activities).
  - Emergency Response (for permits issued).
  - Inmate Labor Records (to track inmate labor activities).
  - Road Weather Information System (for winter maintenance operations, although this may not be necessary).
  - Budget and Finance (disaster recovery and damage repair costs).

- MACS and GIS.
- Highway Development.
- Traffic (including traffic counts and video logs).
- Others (such as hazardous waste or Amber Alerts).

- ***Develop interface with Advantage***. The interface with the Financial Management System will have to meet several requirements to meet the demands of both systems. The primary requirements are listed below:
  - Human resource checks need to be performed in real time without delaying the payroll process. These checks include things such as personnel information, leave balances, overtime eligibility, applicable HR policies, employment verification, and so on.
  - Electronic signatures are needed for both the employee and the supervisor.
  - As changes are made to the payroll process, these changes need to be incorporated into the process used for entering timesheet data for MMS. However, managing and maintaining the interface should not be a significant burden.
  - The MMS requires much more detail on the cost accounting side than the payroll system requires. Therefore, business processes need to be developed to relate the two sets of information.
  - The biweekly payroll process needs to be preserved as does the timesheet format. Timesheets will continue to be processed each Friday.
  - Time should be able to be entered in 15 minute increments.
  - Rules need to be established to define how costs will be addressed in the absence of actual data. Typically, default costs are established for these instances.
  - Advantage uses equipment and material information in terms of dollars. Data for the MMS may be entered in terms of quantities. A process needs to be developed to reconcile these two needs. This will likely require the MMS to apply cost figures from Advantage (or within the MMS) to the quantities entered in the system.
  - A process needs to be developed for charging out pooled equipment to projects (indirect costing).
  - The MMS should be able to adopt the section, unit, project, and object coding structure of the Financial Management System or a conversion process needs to be developed.

Other Needs

- ***Provide a user-friendly interface***. For the system to be used to its fullest extent, it is important that the user interfaces be easy to use, that the outputs are displayed graphically and on maps (through the GIS), and that it is easy to retrieve information from the system. Web access with an easy query function was most often suggested as the desired way to obtain the information.
- ***Provide training to users of the system***. In addition to learning how to operate the software, it is important that field personnel understand the importance of the data entry

activities and how the information is used in planning. This is an important step to help ensure the quality of the data, as discussed earlier in the *Data Needs* section.

- ***Define responsibilities***. Another important step in quality assurance is making sure that everyone understands their responsibilities. This could be established by clearly defining the roles and responsibilities of each position to support, operate, and maintain the MMS.
- ***Develop a plan for long-term maintenance of the system***. The implementation of a system like this is not static and requires consideration of state requirements for data integrity, security, and access that should be addressed by Information Technology (IT). IT prefers to be involved in the planning and acquisition of a system such as this rather than inherit a system that does not meet these requirements. Therefore, IT prefers to be involved early in the planning for this type of software.
- ***Provide system flexibility***. Once the system is implemented, there are undoubtedly changes that will need to be incorporated into the system (such as changes in the maintenance activities being performed). The Department wants to be able to make minor changes to the system without requiring the services of the supplier.

Resulting MMS Gaps

Once the desired capabilities and features were identified, the research team compared the results to their understanding of the current capabilities to determine where gaps existed. In addition, the research team identified the type of work needed to address the gap (i.e. process change, software feature, or other) and the importance of this feature to the Department. The results are summarized in table 1. In preparing table 1, *Process Changes* are defined as changes to the existing business rules, or the way ITD conducts business. *Software Features* are attributes that are expected to be provided in the new software and *Other* includes changes that are not covered by either of the other two descriptions.

Table 1. MMS gap analysis summary.

Level of Importance	Feature Category	Identified Need	Description	Degree to Which Currently Addressed	Explanation	Type of Change Required (P) Process (S) Software (O) Other	MMS & PMS Need	Comments
High	Data needs	Compatible with Advantage	The payroll process requires that certain types of HR checks be conducted in real time as data are being entered so paychecks can be issued on time. The MMS needs more detailed information than is required for payroll purposes. Both needs should be addressed.	Low	Advantage does not track the type and location of work activities. It can not be modified to provide this information.	P,S		
High	Data needs	Data quality checks	Decisions will be based on the information contained in the MMS. Therefore, it is important that the data are accurate and timely.	Low	One point data entry will help to reduce data input errors, but other processes to check data quality are also required. Processes should also be put in place to prevent human intervention that might bias the data used for reporting purposes.	P,S	√	The software should be able to perform some validity checks on the data at the time the data are entered.
High	Data needs	Daily maintenance diaries	In the absence of a MMS, daily activities are reported manually in the foreman's maintenance diary.	Low	This information should be captured electronically and uniformly so the information can be summarized and searches can be conducted.	P,S		The current processes used for recording maintenance activities will change.
High	Information & reporting needs	GIS Displays	There are a number of useful GIS displays that could be developed. For instance, users can display areas with unusually high maintenance expenditures.	Moderate	The MMS will have to be linked to the GIS to display the information desired.	S	√	GIS displays can be done with the current 1-directional approach. However, if the changes to the GIS recommended in the PMS section are made, more effective 2-dimensional displays would be possible.
High	Information & reporting needs	Video Log Displays of MMS Information	Users intend to view video displays of various features while viewing MMS data. This also allows foremen to discuss problem areas with District or HQ personnel.	Low	The MMS will have to link to the video log to display the information desired.	S		

Table 1. MMS gap analysis summary (continued).

Level of Importance	Feature Category	Identified Need	Description	Degree to Which Currently Addressed	Explanation	Type of Change Required (P) Process (S) Software (O) Other	MMS & PMS Need	Comments
High	Information & reporting needs	Basic cost accounting information	Critical information includes the type of work accomplished, the date the work was accomplished, the work location, and the resources (equipment, materials, and labor) used.	Low	At a minimum, the information that was provided in the old MMS is needed to account for how money is being spent.	S		
High	Information & reporting needs	Historical work activities	Reports showing the number of years (or months or days) that have passed since work was last performed.	Low	This information will help with scheduling of work activities and will help the Department respond to tort liabilities.	S		A complete work history provides even more useful information for decision making. While it may be infeasible to build a complete work history, the work history should be built from the time of the MMS implementation forward.
High	Information & reporting needs	Statewide access to data and reporting	The software will be used concurrently by users in disparate locations, including HQ, District offices, and sheds. It should be easy to use and flexible enough to respond to different levels of use.	Low		S		Improvement in access at the shed level may be required in some locations.
High	Information & reporting needs	Disaster and damage recovery reporting	Reports summarizing the amount spent on disaster or damage recovery will be used by Budget and Finance to request reimbursement from FEMA, insurance companies, or other sources.	Low	Some of this information is currently contained in the maintenance diaries so it is not easy to find records.	S		
High	Information & reporting needs	Routine reports	Routine reports will be needed at the State, District, region, foreman, or shed levels. These will include reports that are run regularly, such as historical productivity rates, budgeted versus actual expenditures, planned and scheduled maintenance activities, frequency of maintenance work on a particular asset, and so on.	Low	Routine reports developed for the end users can be called up without the user having to generate a query of the data.	S	√	Not all levels of reporting are critical, but the more flexibility the better.

Table 1. MMS gap analysis summary (continued).

Level of Importance	Feature Category	Identified Need	Description	Degree to Which Currently Addressed	Explanation	Type of Change Required (P) Process (S) Software (O) Other	MMS & PMS Need	Comments
High	Analytical functionality	Productivity rate analysis	Basic cost accounting data to track productivity reports at various levels within the Department.	Moderate	The previous MMS used average cost rates to determine average productivity rates. In the new Financial Management System, cost information is not tied to location or specific activity so it can not easily be used for this type of analysis.	S		
High	Analytical functionality	HQ analyses	At this level, the MMS will be used to determine productivity rates, cost-effectiveness of different activities and work sources, future funding needs, return on investment for maintenance expenditures, costs required to raise the LOS, and resource requirements for new assets.	Low		S		
High	Analytical functionality	District analyses	At this level, the MMS will be used to determine work accomplishments, plan and schedule maintenance activities, determine changes in work crew efficiencies, compare historical trends, establish funding needs, determine material requirements, and identify strategies for budget adjustments.	Low		S		
High	Interfaces with existing systems	Internal and external interfaces	Examples of the types of interfaces that will be required are provided in the summary of needs. Through the interview process, approximately 17 interfaces were identified in the previous section of the report (see page 14).	Low	The most critical interfaces are to the Financial Management System, the feature inventories, the GIS, and the Project Tracking and Contract Administration databases.	S	√	

Table 1. MMS gap analysis summary (continued).

Level of Importance	Feature Category	Identified Need	Description	Degree to Which Currently Addressed	Explanation	Type of Change Required (P) Process (S) Software (O) Other	MMS & PMS Need	Comments
High	Interfaces with existing systems	Financial management interface requirements	There are special requirements for interfacing with Advantage that may require changes to existing processes to meet the demands of both systems. HR checks need to be performed without slowing down the payroll process, electronic signatures should be obtained on timesheets, future changes to payroll should be accounted for, and time should be entered in minutes. The MMS needs more detail than is currently being reported, the coding system in Advantage needs to be preserved (or a conversion developed), location and activity information should be added, MMS equipment and material entries should be converted to costs, and a process is needed for charging out pooled equipment.	Low		P,S		Examples of how some states have addressed these types of issues are provided in the body of the report.
High	Interfaces with existing systems	GASB-34 reporting requirements	A process is needed so maintenance activities, activity date, and work type is available for GASB-34 reporting prior to the close of each fiscal year.	Low		P,S	√	
High	Other needs	User-friendly	The user interfaces should be easy to use, information should be displayed graphically, and an easy query function should be available.	Low		S	√	
High	Other needs	Training	In addition to learning how to operate the software, field personnel need training so they understand the importance of the data they input and how to use the data in decision making. Training should be on-going to refresh skills and to train new crew members. Training is also needed by HQ personnel so they understand the operation of the software and the type of information it can produce.	Low		O	√	

Table 1. MMS gap analysis summary (continued).

Level of Importance	Feature Category	Identified Need	Description	Degree to Which Currently Addressed	Explanation	Type of Change Required (P) Process (S) Software (O) Other	MMS & PMS Need	Comments
High	Other needs	Long-term maintenance plan	The implementation of a MMS needs IT support to help ensure the long-term viability of the system. An oversight team could also be used to review the needs and to set the direction for the implementation.	Low		P	√	
High	Other needs	System flexibility	The Department operates in an environment that constantly changes. Therefore, the system should be flexible enough to adapt to changes in policies, practices, or procedures.	Low		S	√	
Low	Information & reporting needs	GASB-34 reports	Each year the Department reports on the level of pavement maintenance provided. Therefore, Budget and Finance need information on where maintenance activities have been completed.	Moderate			√	Information is often reported long after the work has been completed. This is a problem when the actual completion date is in a different fiscal year than the year in which the work is reported to Budget and Finance.
Moderate	Data needs	Feature inventories	To perform budgeting activities, it is important to have feature inventories in place that track feature type and location (at a minimum).	Moderate	Inventories are in place for the largest assets, such as pavements, bridges, and signs. Excel spreadsheets containing information on guardrails and culverts also exist but no uniform format was used in their development.	S,O		There should be uniformity in the way features are inventoried and reported.
Moderate	Data needs	Feature condition assessment	For budgeting purposes it is also important to be able to determine the current and targeted level of service being provided for various features. Some states assess the condition of a representative sample of each feature to determine conditions while other states survey each of the features in the inventory.	Moderate	An initial method of assessing feature condition was developed by Cambridge Systematics with the PRIMO study. This work serves as a good starting point and could be supplemented with input from other state highway agencies.	P,S		

Table 1. MMS gap analysis summary (continued).

Level of Importance	Feature Category	Identified Need	Description	Degree to Which Currently Addressed	Explanation	Type of Change Required (P) Process (S) Software (O) Other	MMS & PMS Need	Comments
Moderate	Data needs	Single point of data entry	Data entry requirements for the MMS should not duplicate data already being entered into another system. Ideally, maintenance activity data are entered in a computer in the field and uploaded into the MMS when the crews return to the office. There are other techniques that could be used to address this need, such as entering data via portals.	Low	The information is currently being reported in either Advantage (as part of the payroll process) or recorded manually in diaries.	P,S,O	√	To fully implement this need, field computers with docking stations will be needed in each shed and an interface will need to be developed with Advantage.
Moderate	Data needs	Supplemental data provided through interfaces with other data sources	A number of interfaces that need to be established are documented elsewhere in this table. There are several sources of information (such as the Department's crash database, the Idaho State Police, wildlife, and Statewide Communications) that provide information to support MMS decisions.	Low		S	√	
Moderate	Data needs	Actual cost data	In the past, average cost rates were used for labor, equipment, and material costs. Due to regional differences in costs, it is important that more accurate cost information be used in the MMS.	Low		P,S		Regional or statewide averages could be used initially.
Moderate	Data needs	Independent of service provider	Work activities conducted by contract forces, state forces, or inmate labor should be incorporated into the MMS.	Low		P,S		A process for tracking inmate labor was not part of the old MMS and so business processes to support this need do not exist.
Moderate	Data needs	Import/ export capabilities	It will be important to be able to import and export data from sources both inside and outside the Department.	Low	Information from the MMS may be useful to others where direct interfaces have not been developed. Import/export capabilities will enable these transactions to take place.	S	√	

Table 1. MMS gap analysis summary (continued).

Level of Importance	Feature Category	Identified Need	Description	Degree to Which Currently Addressed	Explanation	Type of Change Required (P) Process (S) Software (O) Other	MMS & PMS Need	Comments
Moderate	Information & reporting needs	Transparent access to data	Data table structures and access to information should be provided for generating queries, linking the MMS to new systems, or writing applications.	Low		S	√	
Moderate	Information & reporting needs	Total project cost reporting	Since some projects are made up of multiple activities, it is important that they be able to be combined to get total project costs.	Low		S		
Moderate	Analytical functionality	Planning and budgeting analysis	In addition to reporting productivity information, a MMS can be used to estimate budgeting requirements to meet LOS targets.	Low		S		
Moderate	Interfaces with existing systems	Centralized database or shared database structure	The MMS is expected to pull information from various sources as listed in the body of the report. If a client-distributed database structure is available, the data do not all need to be located in a single database, but access to the information is established in a manner that is transparent to the user.	Low		S	√	It may be helpful to establish priorities for developing links to different data sources so the initial efforts ensure that the most important information is available.
Low	Information & reporting needs	Dashboard reporting	Dashboards provide a means of visually monitoring accomplishments toward a target without having to run a report (they are displayed as a user logs onto the system).	Low		S		
Low	Other needs	Clear responsibilities	An important component of quality assurance is to have clearly defined roles and responsibilities for supporting, operating, and maintaining the MMS.	Low		O	√	

Process Changes – Changes to existing business rules or the way ITD conducts business.
Software Feature – An attribute expected to be provided as part of the software.
Other – A Change that is not covered by either of these descriptions.

CHAPTER 3.0 – PAVEMENT MANAGEMENT NEEDS ASSESSMENT AND GAP ANALYSIS

A needs assessment and gap analysis were also conducted to determine the need for new pavement management software. Whereas ITD currently has no computerized MMS in place, there are several pavement management tools being used by the Transportation Planning Division and by District 6. To better understand the pavement management needs described in this chapter, a brief summary of the tools that are in place is provided. Following the description of the existing pavement management capabilities are the needs that were determined from the interviews of Departmental personnel, a review of the available resources, and the research team's knowledge of pavement management. The needs are grouped into the following four areas:

- Data needs.
- Information and reporting needs.
- Analytical functionality.
- Interfaces with existing systems.

The results of the gap analysis, which identifies the degree to which each need is currently addressed, its relative importance to the Department, and the type of change required to eliminate the gap (i.e., process change, software feature, or some other type of change), is presented in a summary table at the end of the chapter.

Existing Pavement Management Capabilities

Pavement management systems have the ability to support a transportation agency's decision processes at three different levels. Most commonly, pavement management provides support at the network level where decisions are made about the best use of available funds after the needs of the agency's entire pavement network are considered. At the network level, pavement condition information is collected and used to determine existing funding needs and to project how those needs are expected to change in the future. Many state highway agencies also use pavement management at the network level to identify candidate projects for pavement preservation and/or capital improvement programs.

Pavement management can also be used to support decisions at the project level, which is the level at which the most cost-effective design is developed for projects included in the State Transportation Improvement Program (STIP). The project level usually involves a more detailed assessment of in-situ conditions than can be conducted at a network level.

The third level of decisions supported by pavement management is the strategic level. At this level policy and investment decisions are made, often using the results of a network-level pavement management analysis. Pavement management information can also be used to support an agency's long-term strategic planning and to help set realistic performance targets for the pavement network that consider anticipated funding levels.

Most state highway agencies use pavement management software program to support decisions at each of these levels, although additional tools may be used to incorporate factors not typically considered in a pavement management system. For instance, most pavement management

systems do not consider capacity issues when recommending candidate projects for improvement. Therefore, other tools may be necessary to consider these other types of issues when making investment decisions.

The Department's current pavement management system is limited in its ability to meet the needs of District personnel. Discussions with ITD personnel indicate that there are issues with data accessibility that limit the usefulness of the pavement management information and the recommendations provided at the network level (which are based primarily on needs) are not reflective of more cost-effective preservation strategies that incorporate the use of preventive maintenance treatments. To some degree, these issues are related to the types of tools currently being used by ITD. Therefore, an overview of the existing tools is provided.

Use of Pavement Management By the Transportation Planning Division

The pavement management system used by the Transportation Planning Division provides an assessment of pavement needs determined from annual pavement condition surveys. Needs are defined in terms of deficient pavements, which are identified when the results of the pavement condition surveys indicate that pavement conditions are below a certain level. The percentage of pavements that are considered to be deficient are reported regularly to the legislature and every other year to the FHWA, and District Engineers are evaluated (in part) on the percentage of deficient miles in their District. Therefore, the selection of projects is oriented towards reducing or eliminating the number of miles of deficient pavement. Interviews with ITD Management indicate that they plan to continue reporting deficient miles to the legislature because the measure is understandable and useful to the legislature.

The analysis used by ITD's Division of Transportation Planning, which focuses on addressing deficient pavements (a *worst first strategy*), may lead to worse long-term conditions than an alternate strategy that includes some preventive maintenance to keep pavements in good condition longer. Most of the District personnel reported that they want to utilize preventive maintenance treatments but since these types of projects do not eliminate reported deficiencies, there is little incentive to do so. The current software has limited ability to forecast future conditions and to evaluate alternate treatment strategies that focus more attention on preservation strategies.

The Transportation Planning Division is responsible for conducting the annual pavement condition surveys. As part of the survey process cracking data, roughness information, and rut depths are colleted. The information is reported in terms of an Overall Condition Index (OCI), a cracking index, and a roughness index. Because the current equipment used to assess road condition does not provide sufficiently accurate rut data, this information is not used in determining pavement needs. Also, although distress type, severity, and extent are collected, used to calculate the cracking index, and reported in terms of an index in the *Pavement Performance* Reports, the information is not easily accessible to the Districts in time for its use in design. The Transportation Planning Division is acquiring a new van to address the problems with rutting data, but new models will need to be developed to incorporate that information into the analysis of needs.

Pavement management reports that they were one of the first to interface with the GIS. However, there are reportedly some issues that occur because the video log van reports mileage based on a reference post and off-set method that does not match the continuous collection method used in the linear referencing system. This difference causes discrepancies at the end of measured distances between mileposts that are visible when watching the video log. An

additional administrative problem is that the video log van keys mileage to the Route Number and milepost rather than the Segment Code used for all other data. Even so, the availability of the digital images from the video log was reported to be very useful to District personnel because it allows them to address problems in remote locations by phone rather than mobilize people to the site.

Another tool used by the Transportation Planning Division is the Highway Economics Requirements System – State Version (HERS-ST) developed and distributed by the FHWA. HERS-ST is not considered a pavement management system by the FHWA. Rather, it is a planning tool that analyzes capacity, safety, and condition investment needs over an analysis period. HERS-ST analyzes needs in a manner that is similar to the pavement management analysis and then optimizes the use of available funds to address the three types of needs. HERS-ST includes models that can predict changes in condition with time and so it provides a tool for forecasting future conditions. However, the pavement condition needs are based entirely on ride and ignore other types of pavement deterioration. Additionally, spending is optimized only on needs and so alternate treatment strategies (such as using preventive maintenance) can not be considered.

District 6 Pilot Pavement Management Program

The Districts are responsible for recommending preservation, restoration, and reconstruction projects for inclusion in the STIP. The Districts are also responsible for designing appropriate treatments within the funding constraints established. In the absence of information from the Transportation Planning Division that would evaluate the trade-offs between different treatment strategies, District 6 worked with a contractor to develop and implement a customized version of CarteGraph's pavement management software, PavementView Plus, under a pilot program.

Pavement management systems are typically structured in one of two ways: either data are stored in accordance with a rigid segmenting structure or data are stored in whatever manner is convenient and rules are developed to dynamically segment the data into reasonable lengths. The latter approach, which is the currently preferred approach in high-end pavement management systems, provides an agency a great deal of flexibility and is commonly referred to as *dynamic segmentation* or *concurrent transformations*. When District 6 implemented its pavement management system it elected to use dynamic segmentation and developed a routine that uses the Department's GIS to dynamically segment the data before being analyzed in the PavementView Plus software.

The PavementView Plus software is capable of analyzing the impacts of different treatment strategies over a multi-year period. It includes pavement performance models that predict the change in pavement conditions over time and treatment rules that define the conditions that should exist for different types of treatments to be used. For instance, treatment rules could be defined that permit chip seals to be considered on a low-volume facility but not on a high-volume facility. By establishing multiple sets of treatment rules, different strategies can be evaluated. In other words, one set of treatments could include projects to address deficient projects and another set could include a combination of preservation, restoration, and reconstruction alternatives. The pavement management system can analyze the predicted conditions for each set of treatments at the same funding level and determine which strategy results in the best network conditions five or ten years into the future. The software can also help determine the combination of projects (and treatments) that make the most cost-effective use of available funds. Although there are pavement management systems available

commercially that provide more flexibility than the PavementView Plus software (in terms of the number of condition indices that can be used and the variables that can be used to develop performance models and treatment rules), and this additional flexibility may be needed if the program were to be used at the Statewide level, the software reportedly satisfies the needs of the District 6 staff for programming projects and allows them to demonstrate to the Board the consequences of various expenditures.

Identified Pavement Management Needs

Based on a review of the available references, the feedback provided during the interviews, and the research team's knowledge of pavement management practices, the following pavement management needs have been identified.

Data Needs

- ***Improve access to pavement distress information for treatment selection***. Although the current pavement condition rating procedure is relatively quick to conduct, the summary information reported to the Division of Highways is not sufficient for treatment selection. Additionally, by the time Needs Reports are published, the information is dated, limiting its value to District personnel. Better, more timely access to the detailed information that is currently collected on distress type (i.e. crack type), severity, and quantities is needed in addition to the calculated indexes. Further, because the current equipment used to assess road condition does not provide sufficiently accurate rut data, this information is not used in determining pavement needs. The Division of Transportation Planning is purchasing a new van that should address the data quality issues but models will need to be developed to incorporate this information into the determination of needs.
- ***Improve access to other pavement-related data useful for design***. In addition to the pavement distress information, Division of Highways personnel need access to construction histories and geometric data, such as roadway width and shoulder information to determine whether lane and shoulder widths are adequate prior to repair. This information is available by requesting the information from the Division of Transportation Planning, but Division of Highway personnel would prefer being able run queries to obtain the information themselves. The results of nondestructive deflection testing, which are used in pavement overlay thickness design, are stored in project report files. This means that the information is not easily accessible by others and it is difficult to track historical trends.
- ***Address Linear Referencing System issues to facilitate the use of GIS for displaying information***. The video log van used to collection pavement condition information does not collect distance data consistently with the way the Department's Linear Referencing System collects, stores, and manages data. Specifically, the video log van collects data based on a reference post method rather than the continuous method used for other data. The video log van also stores distances by Route and milepost, rather than the segment code used in the LRS for other data. It is important that these data inconsistencies caused by the different methods of collecting, storing, and managing data be addressed to ensure consistency and accuracy in viewing the video logs.

  As discussed in the previous chapter, the GIS has been designed to display information in only one direction. While this is better than having no GIS in place, it is not possible to differentiate between work performed on lanes in each direction. This could become important if the Department wants to display the location of nondestructive testing

locations (for example) or if different maintenance and construction activities are performed in each direction of travel. When asked to provide an example of using different treatments in each direction of travel, District personnel reported that different work activities are often performed on climb lanes in areas with dramatic elevation changes.

- ***Provide an open data structure***. This is important so that scripts and other applications can be developed using the information contained in the pavement management system. There are currently no applications that have been defined, but it is feasible that a District would want to run a performance analysis of all pavements with a particular type of treatment over time. To do so, the District needs to be able to access the data structure so the query can be structured. It is also important to maintain interfaces with other existing systems. Data names, uses, and formats should be clearly identified. Complete metadata would also be useful to describe the context, content, and data structure as well as the plan for data management over time.
- ***Provide the ability to import and export data***. It is important that information from the pavement management system can be imported or exported to other systems both within ITD and outside ITD. Therefore, the software should be able to export directly to Microsoft Office programs and should be able to read/produce comma-delineated files (and other data formats).

Information and Reporting Needs

- ***Improve access to pavement management information***. The current pavement management database is not accessible by field personnel so these individuals must request reports from the Division of Transportation Planning to obtain the information. According to the District staff, by the time it is provided, it is often too late to be useful. Therefore, web access or client-server access to pavement management information is desired.
- ***Provide a centralized database for access to more pavement-related information***. There are currently no interfaces between the pavement management database and other sources of pavement-related data, such as the results of the nondestructive deflection testing using the FWD or work history activities. This requires an expanded database where project-level test results can be stored so it is more easily accessible in future years.
- ***Report the International Roughness Index to the FHWA***. Roughness information is currently reported in terms of a Roughness Index. While suitable for internal use, the FHWA requires that roughness be reported in terms of the International Roughness Index (IRI) for Highway Performance Monitoring System (HPMS) reporting. So far, the FHWA has allowed exceptions to the IRI from ITD; however, there is no assurance these exceptions will be allowed in the future (especially in light of the fact that the FHWA is developing more stringent HPMS reporting requirements that for use in 2010). Therefore, the Department needs to develop a plan for using IRI data separately in its pavement management system or using it to determine the Roughness Index.
- ***Increase the use of GIS displays***. There are a number of different types of graphical displays that would be helpful to users within the Division of Highways. For example, a map showing pavement sections that have not been sealed for the past 7 years would enable field personnel to quickly identify potential candidates.

- ***Provide basic pavement management data in real time***. The basic pavement management information desired by the Districts includes the identification of candidate projects, a summary of when work was conducted on each road segment in the District, what type of work was conducted in the past, and what is the current and predicted condition. Currently this information can be produced in reports, but real time access to this information is desired.
- ***Provide expanded access to all potential users of the pavement management system***. A statewide license for the pavement management software is recommended because of the number of people expected to access it in some form or another. Some will have limited access to the pavement management system so they can run reports and queries. Each District should be able to have access to run an optimization analysis for their road network and the Division of Transportation Planning will need full access to generate planning reports and to feed the HERS-ST system.
- ***Provide information on the consequences of inflation***. The budget is largely driven by inflation, a factor that can not be controlled by the Department. It will help individuals from the Division of Budget and Finance if the consequences of inflation on the network conditions could be evaluated. Most pavement management systems allow an agency to input an inflation factor into the analysis, so generating a report showing consequences of different inflation rates on network conditions should not be difficult to produce.

Analytical Functionality

- ***Add analytical functionality to support decisions at the strategic, network, and project levels***. The current analysis provides some capabilities at the network and strategic levels to support the existing business processes. However, if the agency decides to make more use of preventive maintenance treatments, the functionality of the pavement management software is not sufficient to perform that type of analysis. In addition to more robust optimization analysis capabilities, alternate sets of treatment rules should be developed so that different preservation strategies can be evaluated. Most state highway agencies use fairly sophisticated treatment rules that consider multiple condition variables (such as type of cracking, roughness, and rutting) with inventory characteristics to determine candidate projects and treatments. Without these sophisticated treatment rules, the pavement management system does not adequately meet the needs at the project level. To adequately address the needs of the field personnel, real time access to more detailed pavement distress data (distress type, severity, and extent) is needed in addition to the index information currently being reported. A broader range of treatment options (that include preservation, restoration, and reconstruction options) that makes more cost-effective use of the available funding within each District is also desired in the pavement management analysis. In summary, the pavement management system should be able to compare different treatment strategies, recommend candidate projects and treatments for the selected treatment strategy, and document the performance expected under each strategy in addition to generating the needs reported by the Division of Transportation Planning.
- ***Implement new optimization analysis capabilities***. The current pavement management strategy identifies pavement needs based on definitions for when a pavement is considered to be deficient. This approach tends to place more emphasis on repairing the roads in worst condition, which is a very costly strategy. More optimal pavement preservation strategies can not easily be evaluated because there is no mechanism for

evaluating alternate treatment strategies that include preventive maintenance. Therefore, a pavement management system that can compare the results of a number of intervention strategies (including strategies that preserve pavements without extensive deterioration) is needed. This will also enable the Department to determine the optimal allocation of funding to different types of activities (e.g., maintenance, preservation, and resurfacing).

- ***Establish a broader definition for defining pavement needs***. The current strategy for defining needs uses functional class to describe intervention levels. According to the *2007 Pavement Performance Report*, pavement sections are considered to be deficient if they are classified as *Poor* or *Very Poor*. *Poor* pavements are defined as those with condition indices between 2.0 and 2.5 on interstates and arterials or between 1.5 and 2.0 on collector routes. Interstate and arterial pavements are considered to be in *Very Poo*r condition if the lowest condition index falls below 2.0. On a collector route, a road is considered to be *Very Poor* if the lowest rating is below 1.5. Since traffic levels vary significantly within a functional classification, it is important that additional criteria be considered in the definition of needs.
- ***Expand pavement performance modeling capabilities***. It is important to be able to predict the future condition of different types of treatments and to evaluate whether pavement sections have performed as expected as part of an engineering analysis. The models will also be useful for demonstrating the future consequences of different funding levels on network conditions. This requires a pavement performance modeling tool that is integrated into the pavement management software with sufficient functionality to take into consideration the factors that contribute to different rates of pavement deterioration around the State.

Interfaces With Existing Systems

- ***Provide information needed for GASB-34 reporting***. Information on maintenance and construction activities and the dates these projects are completed is required as soon as possible after the project is accepted by the Department. Therefore, a process needs to be developed so this information is available for updating the pavement management database and for GASB-34 reporting. Some of this information currently comes from the Construction Status Reports and Project Tracking database, but these are not the only sources of information. Because of existing time lag in receiving the information, some project completion dates are reported in a different fiscal year than the work was actually completed. This requires adjustments to the prior years' financial reports and raises flags with the auditors. Consistent use of treatment coding between systems is also required to limit the amount of manual manipulation of the data. The percentage of miles in each of the four condition categories (*Good, Fair, Poor,* and *Very Poor*) is required annually for the current year and four prior years and an estimate of the cost required to meet the targeted threshold is needed annually.
- ***Develop an interface with the new MMS***. In the past, a link between the old MMS and PMS did not exist. However, coordinated capital and maintenance improvement plans require that an interface exists between these two programs so information can be shared. For example, information on segments where extensive maintenance has been performed may become a higher priority to receive a capital improvement than another segment.
- ***Address the data collection inconsistencies with GIS to facilitate a better interface with pavement management***. As mentioned earlier, distances collected by the video log van are measured differently than how other data are collected, which causes inconsistencies

with the Linear Referencing System. These types of inconsistencies will have to be addressed if GIS will be used more as a tool for aggregating data sources and displaying pavement management information.

- ***Develop a database to store project-related test results so the information can be used in project level treatment selection***. The Materials section conducts skid testing and nondestructive deflection testing to support the Department's design functions. Currently, this information is used at the project level and test results are stored with project files. Having a centralized database that would allow this information to be stored and accessed by District personnel will allow the information to be used for evaluating future treatment options. Since this type of information is not expected to be used in the network-level models in the pavement management system, there is no problem having this information available on only a limited number of pavement sections.
- ***Develop processes to keep the work history information current***. Processes are currently in place for updating the pavement management system with information about last construction dates from the Construction Status Reports and Project Tracking database. If new pavement management software is implemented, interfaces with these databases should be developed to keep the work history information current.
- ***Maintain existing interfaces with new pavement management software***. There currently exist a number of interfaces with pavement management to define transportation and environmental features, structures, segment location, traffic, and crash data. These links need to be preserved in the new pavement management software.

Other Needs

- ***Initiate pavement management training***. There is a need for training to teach pavement management concepts and the various levels at which pavement management information is used to support an agency's decision processes.
- ***Develop a plan for the long-term maintenance of the system***. The implementation of a system like this is not static and requires consideration of state requirements for data integrity, security, and access that should be addressed by Information Technology (IT). IT prefers to be involved in the planning and acquisition of a system such as this rather than inherit a system that does not meet these requirements. Therefore, IT prefers to be involved early in the planning for this type of software.
- ***Select a system that is flexible enough to change with time***. Once the system is implemented, there are undoubtedly changes that will need to be made (such as changes in the types of treatments being performed or the rate of pavement deterioration taking place). The system should be flexible enough to allow the Department to make these changes without requiring services from the supplier.

Resulting Pavement Management Gaps

Once the desired capabilities and features were identified, the research team compared the results to their understanding of the current capabilities to determine where gaps existed. In addition, the research team identified the type of work needed to address the gap (i.e. process change, software feature, or other) and the importance of this feature to the Department. The results are summarized in table 2. In preparing table 2, *Process Changes* are defined as changes to the existing business rules, or the way ITD conducts business. *Software Features* are attributes that

are expected to be provided in the new software and *Other* includes changes that are not covered by either of the other two descriptions.

Table 2. Pavement management gap analysis summary.

Level of Importance	Feature Category	Identified Need	Description	Degree to Which Currently Addressed	Explanation	Type of Change Required (P) Process (S) Software (O) Other	MMS & PMS Need	Comments
High	Data needs	Consistent Linear Referencing Systems (LRS)	The reference post/off-set method of collecting pavement condition data conflicts with other methods of continuous data collection. This can lead to discrepancies in location referencing that vary depending on the direction of travel.	Low	Discrepancies in data location can result in a lack of confidence in the pavement management system and leads to inefficiencies in managing data.	P		
High	Information & reporting needs	Real-time access to the pavement management database	Timely access to pavement-related information allows pavement condition information to be used when it is needed, rather than when reports become available.	Low	Web access through a client-server environment is desired.	P,S,O		The Department could elect to make the pavement management database the central repository for all pavement-related information and specify that requirement in the solicitation for new software. However, if the Department is currently addressing other database issues, this could be done on a Department-wide basis that would result in a much more substantial effort, which is not assumed as part of this project.
High	Information & reporting needs	International Roughness Index (IRI) rather than Roughness Index for reporting to FHWA	The FHWA's Highway Performance Monitoring System (HPMS) requires that roughness data be reported in terms of the IRI. ITD currently reports it in terms of a Roughness Index and has been able to get exceptions from the FHWA to report it this way. However, the FHWA is updating its reporting requirements and it is possible that an exception may not be granted in the future.	Low	If the FHWA continues to grant exceptions to the reporting requirement, this change is not required and becomes a lower priority.	P		IRI data can be converted to the Roughness Index if ITD elects to continue using that measure to determine needs.

Table 2. Pavement management gap analysis summary (continued).

Level of Importance	Feature Category	Identified Need	Description	Degree to Which Currently Addressed	Explanation	Type of Change Required (P) Process (S) Software (O) Other	MMS & PMS Need	Comments
High	Information & reporting needs	Remote access to pavement management information	It is estimated that both District and HQ personnel will access the pavement management database at some level. Some will be power users who perform analyses, but others will primarily perform queries or run reports.	Low	Examples of the type of information sought by users includes a listing of candidate projects, work history summaries, current condition, and predicted condition.	S		
High	Analytical functionality	Analysis support for decisions at the strategic, network, and project level	A pavement management system should support decisions at the strategic, network, and project levels.	Moderate	The current pavement management system addresses most of the needs identified by Planning, but does not address the needs of the Division of Highways to develop lists of candidate projects (network level). For example, the current business processes do not differentiate between the types of cracks; however, this is very important information for selecting and designing a repair. The system also reports deficiencies in terms of roads in poor or very poor condition although the Districts want to include treatments requiring earlier intervention.	P,S		The ranking for a high level of importance assumes that the Department is interested in considering treatment strategies that make use of preventive maintenance treatments.

Table 2. Pavement management gap analysis summary (continued).

Level of Importance	Feature Category	Identified Need	Description	Degree to Which Currently Addressed	Explanation	Type of Change Required (P) Process (S) Software (O) Other	MMS & PMS Need	Comments
High	Analytical functionality	Optimization analysis of alternate strategies	The current pavement management system supports many of the decisions at the strategic and network level, especially reports needed for planning purposes. The current software is somewhat constrained in the type of analyses that can be conducted, which limits its usefulness at other levels within the Department.	Low	The current pavement management analysis is driven by needs. Alternative strategies, such as those including the use of preventive maintenance treatments can not be analyzed. As a result, the Department may not be optimizing its use of available funding.	P,S,O		In addition to the software requirement, the Department will need to develop treatment rules and performance models for the treatments added to the analysis. This will also require changes to the Department's existing business rules.
High	Analytical functionality	Broader definition of needs	The current strategy for defining needs uses functional class to describe intervention levels. Since traffic levels vary significantly within a functional classification, the current definitions do not always adequately define realistic needs.	Moderate	There are some low-volume roads that are currently defined as reconstruction needs, even though these roads will not be reconstructed within the current funding environment. While it may be accurate to report these needs to the legislature, alternate (and more realistic) strategies are needed by the District for developing their list of candidate improvements.	P,S		There is a need to preserve the definition of needs at some level since this information is familiar and useful to the legislature.

Table 2. Pavement management gap analysis summary (continued).

Level of Importance	Feature Category	Identified Need	Description	Degree to Which Currently Addressed	Explanation	Type of Change Required (P) Process (S) Software (O) Other	MMS & PMS Need	Comments
High	Analytical functionality	Pavement performance modeling	Planning has developed some pavement performance models for its purposes, but the models have not been used to support engineering analyses. Ideally, a pavement performance modeling tool is built into the pavement management system.	Moderate		S,O		Pavement performance models are required for each treatment considered in a pavement management system.
High	Interfaces with existing systems	GASB-34 reporting requirements	A process is needed so pavement restoration and reconstruction information are available for GASB-34 reporting prior to the close of each fiscal year.	Low		P,S	√	
High	Interfaces with existing systems	Consistencies in data collection processes for GIS	The pavement condition survey data are collected using a mile posts and offsets. This approach causes conflicts with the continuous measures used in GIS that cause inefficiencies and may lead to data errors.	Low		P		
High	Interfaces with existing systems	Work history records	As improvements are made to the pavement network, it is important that any activity that resets the condition indexes, resets the last resurfacing date, or changes the surface type are reported to pavement management on a timely basis.	Moderate	Several sources of this information currently exist. Improvements in the process will also support the GASB-34 reporting requirement.	P	√	

Table 2. Pavement management gap analysis summary (continued).

Level of Importance	Feature Category	Identified Need	Description	Degree to Which Currently Addressed	Explanation	Type of Change Required (P) Process (S) Software (O) Other	MMS & PMS Need	Comments
High	Interfaces with existing systems	Preservation of existing interfaces	The current pavement management software interfaces with a number of different sources to define transportation and environmental features, segment location, and traffic data. These links need to be preserved to provide basic inventory information critical to pavement management.	High		S		
High	Other needs	User-friendly	The user interfaces should be easy to use, information should be displayed graphically, and an easy query function should be available.	Low		S	√	
High	Other needs	Training	Several different types of training are needed to teach pavement management concepts and the use of pavement management information to support decisions at each of the three levels (strategic, network, and project levels).	Low		O	√	
High	Other needs	Long-term maintenance plan	Processes should be developed to help ensure the long-term viability of the pavement management system if new software is implemented.	Low		P	√	
High	Other needs	System flexibility	The Department operates in an environment that constantly changes. Therefore, the system should be flexible enough to adapt to changes in policies, practices, or procedures.	Low		S	√	

Table 2. Pavement management gap analysis summary (continued).

Level of Importance	Feature Category	Identified Need	Description	Degree to Which Currently Addressed	Explanation	Type of Change Required (P) Process (S) Software (O) Other	MMS & PMS Need	Comments
Moderate	Data needs	Detailed distress information	Information on the type, severity, and extent of cracking information is collected as part of the annual pavement condition surveys but the information is not easily accessible to District personnel. Rutting information has not been incorporated into the deficiency calculations due to a lack of confidence in the data.	Low	The type, severity, and extent of cracking influences the type of repair needed.	S		Improved rutting information is expected to be available with the new data collection equipment.
Moderate	Data needs	Pavement-related information useful for design	Real time access to information on pavement construction history, geometrics (roadway width and shoulder information), deflection testing.	Low	Although much of this information is verified through field visits, improved access to reliable information will improve the efficiency of the design process.	S		
Moderate	Data needs	Two-directional GIS displays	GIS data is stored and reported using a single line to represent both directions of travel. To display work activities by direction or to link data to particular lanes requires modification to the existing GIS.	Low		P,O	√	This activity requires changes to the existing GIS structure that are incorporated into the cost estimates provided in chapter 5.
Moderate	Data needs	Transparent access to data	Data table structures and access to information should be provided for generating queries, linking the PMS to new systems, or writing applications. Complete metadata that describes data context, content, structure, and management would also be useful.	Low		S	√	

Table 2. Pavement management gap analysis summary (continued).

Level of Importance	Feature Category	Identified Need	Description	Degree to Which Currently Addressed	Explanation	Type of Change Required (P) Process (S) Software (O) Other	MMS & PMS Need	Comments
Moderate	Data needs	Import/export capabilities	It will be important to be able to import and export data from sources both inside and outside the Department.	Low	Information from the MMS may be useful to others where direct interfaces have not been developed. Import/export capabilities will enable these transactions to take place.	S	√	
Moderate	Information & reporting needs	Centralized storage of pavement-related information	Pavement-related information is currently stored in disparate locations, further hindering the access to this information. For example, nondestructive deflection testing and skid test results are typically stored in project files rather than in the pavement management database.	Low	Access to nondestructive deflection testing or work history information can not easily be combined with pavement condition information.	P,S,O		
Moderate	Information & reporting needs	GIS Displays	There are a number of useful GIS displays that could be developed. For instance, users can display pavement sections that have not been sealed for 7 or more years.	Moderate	Some GIS displays of pavement management information are currently being provided. However, increased access to the pavement management data provides an opportunity for users to produce maps directly.	S	√	
Moderate	Interfaces with existing systems	MMS interface	Coordinated capital and maintenance improvement plans require that an interface exists between pavement management and MMS to assist in the project selection process.	Low	Specific information requested include a summary of recent maintenance activities and total maintenance expenditures on a particular route.	S	√	

Table 2. Pavement management gap analysis summary (continued).

Level of Importance	Feature Category	Identified Need	Description	Degree to Which Currently Addressed	Explanation	Type of Change Required (P) Process (S) Software (O) Other	MMS & PMS Need	Comments
Moderate	Interfaces with existing systems	Central location for all pavement-related information	Pavement-related data are stored in various locations depending, primarily on the data source. A centralized, client-server architecture would improve access to information collected by different sources.	Low	Access to nondestructive deflection testing or work history information can not easily be combined with pavement condition information, for example.	P,S,O		
Low	Information & reporting needs	Consequences due to inflation	The budget is largely driven by inflation, which can not be controlled by the Department. It would be helpful to some users to be able to evaluate the consequences of inflation on future network conditions.	Low		S		

Process Changes – Changes to existing business rules or the way ITD conducts business.
Software Feature – An attribute expected to be provided as part of the software.
Other – A Change that is not covered by either of these descriptions.

CHAPTER 4.0 - HIGHLIGHTS OF PRACTICES IN OTHER AGENCIES

When evaluating implementation options, it can be beneficial to compare practices with other similar types of organizations. Originally, the project scope included a task to conduct a survey of state highway agencies to learn more about their maintenance management and pavement management practices. However, to better match the project scope to the budget, and to complete it within the schedule provided, the research team instead proposed to contact SHAs that had recently implemented new maintenance management software and rely primarily on the team's knowledge of pavement management practices to document what other states are doing. This chapter of the report summarizes the findings from these activities and presents information that might be helpful in evaluating the implementation options presented in Chapter 5.

Maintenance Management

Maintenance management capabilities have advanced dramatically in the past ten years as technology has made remote access possible and computer programs have developed to provide performance-based budgeting capabilities. In 2005, the American Association of State Highway and Transportation Officials (AASHTO) published its *Guidelines for Maintenance Management Systems,* which lists the following roles for a MMS (AASHTO 2005):

- Support decision makers at all organizational levels – senior management, budget decision makers, and front-line operational managers.
- Assist managers in determining outcomes of various investment and funding scenarios.
- Optimize maintenance expenditures by developing annual work programs that achieve the highest LOS within available funding.
- Manage resources at the field and statewide level based on adopted annual work programs.
- Provide field managers with strategic and tactical tools to execute the maintenance program efficiently and deliver quality customer service.

At the same time, the FHWA developed a course on MMS and, as part of the course development, a survey of state practice was conducted to identify MMS characteristics in SHAs. The results of the survey are included in their entirety as Appendix A (Zimmerman and Wolters 2005). The survey indicates that 20 of the 29 responding agencies had updated their MMS, or were in the process of updating their MMS, in the past 10 years. Most of the newer systems involved implementing a proprietary software program that was customized to match the agency's business processes.

One of the questions included in the survey asked agencies to identify planned enhancements to their existing MMS capabilities. The results, which are provided in figure 1, indicates that the greatest number of agencies are developing interfaces with other existing systems, developing methods of establishing LOS, setting performance targets, and updating their asset inventory. All of these features should be in place to conduct performance-based budgeting activities.

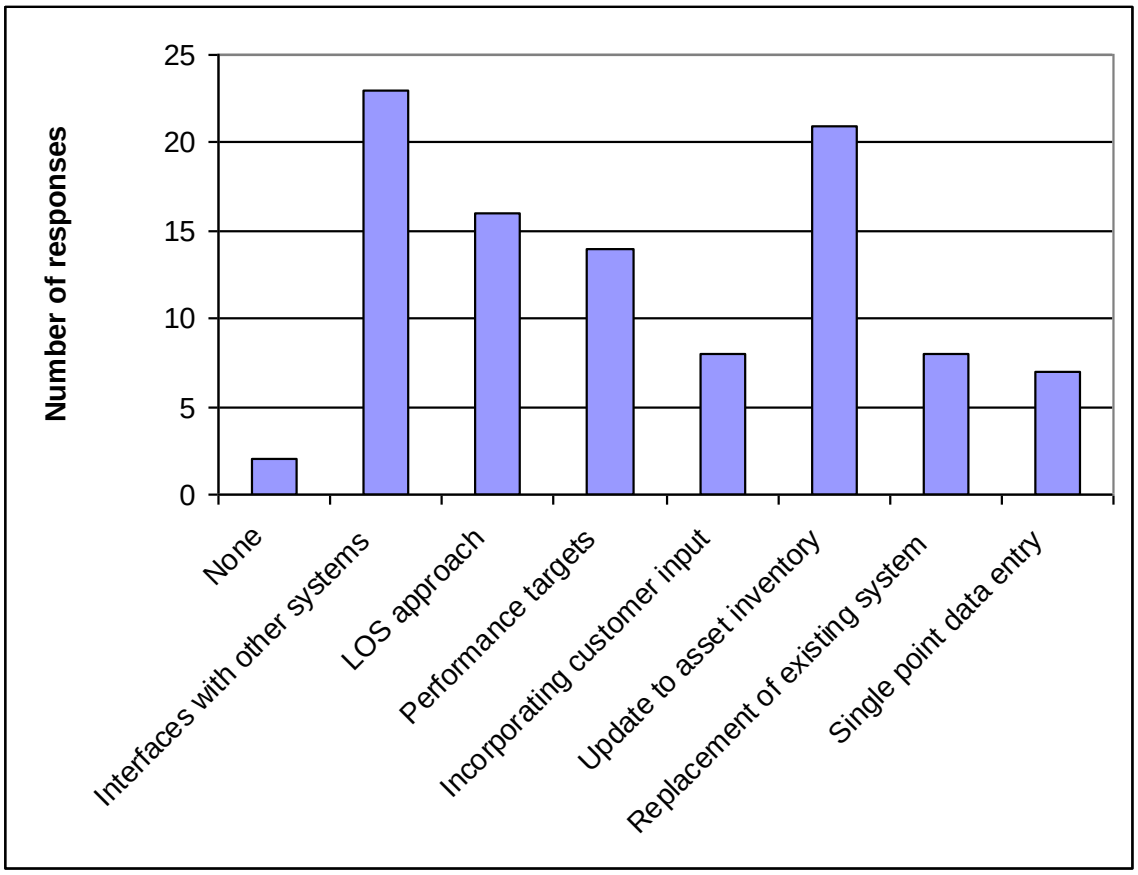

Figure 1. Planned enhancements to existing MMS in SHAs.

This section of the report describes characteristics of the MMS activities implemented by several SHAs in the following areas:

- Software.
- Features.
- Interfaces.
- Costs.

A summary of general observations is also provided.

Software

There are a number of sources for maintenance management software in the industry today. A significant number of states have recently implemented the Maintenance Manager software developed by AgileAssets. However, there are a number of other programs currently available. A list of vendors with experience in state highway agencies is provided in table 3. In addition to these commercial packages, some states (e.g. Washington State) have elected to develop a customized software package that is tailored to meet their specific needs.

Table 3. MMS software vendors with DOT experience.

Vendor	Address	Software Product	Sample Client List
AgileAssets	2602 Dellana Lane Austin, TX 78746-5746 www.agileassets.com	Maintenance Manager	Wyoming DOT North Carolina DOT Utah DOT
Hansen Infrastructure Technologies	1745 Markston Road Sacramento, CA 95826-4026 www.hansen.com	Hansen 8 Maintenance/Work Management	California DOT
Telvent Farradyne, Inc.	3206 Tower Oaks Blvd. Rockville, MD www.telvent-farradyne.com	Transportation Infrastructure Maintenance Management Software (TIMMS)	Virginia DOT (at their Smart Traffic Center) D.C. Department of Public Works (for their Traffic Signal System)
IBM Maximo Asset Management	Various Business Partners are listed on the web site, but all appear to be more municipal oriented www.ibm.com/software/tivoli	Tivoli Asset Management for IT, Version 7.1	City of Portland
Delcan	625 Cochrane Drive, Suite 500 Markham, Ontario L3R 9R9 www.delcan.com	Customized packages for its clients	Maine/New Hampshire/Vermont DOTs (in a cooperative project)
CitiTech	P.O. Box 7626 Rapid City, SD www.cititech.com	CitiTech Management Software	Mississippi DOT

There are many other MMS programs available (e.g. IBM's Maximo Asset Management, Mapcon Technologies, and GBA Master Series MMS) but these companies do not list experience with an agency equivalent in size and complexity to a SHA.

Features

Most of the commercially-available MMS provide similar features, although there are differences in the flexibility, transparency, and accessibility of the tools. Although most SHAs use their MMS primarily for cost-accounting functions, a recent survey of state practice indicates approximately 30 percent of SHAs are also using their MMS to conduct performance-based budgeting activities (Zimmerman and Stivers 2007b). Under this type of approach, methods of assessing maintenance quality (such as Level Of Service) are used to set performance targets that represents realistic expectations for the agency's condition objectives that are linked to budget levels. Work activities are scheduled once these priorities are established and resources are deployed in accordance with annual work programs. Performance is then monitored through the regularly scheduled condition assessment surveys and any necessary adjustments are made to the program. This process is illustrated in figure 2.

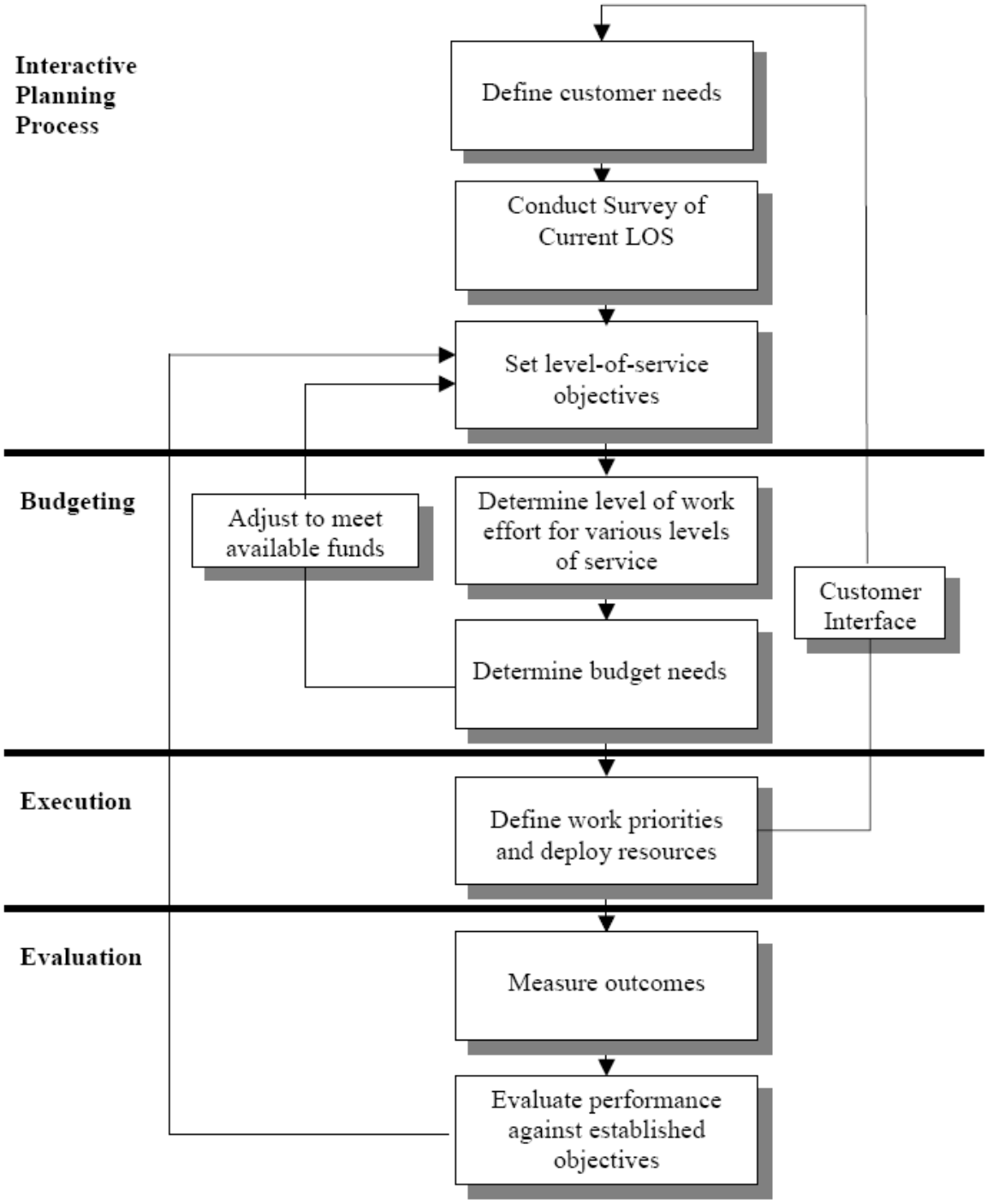

Figure 2. Flow of information in a performance-based maintenance organization (Dye Management Group, 2005).

Before an agency can conduct performance-based budgeting, it should have in place a method of assessing current and targeted feature conditions. Many agencies refer to these surveys as Maintenance Quality Assurance (MQA) surveys. These agencies establish different condition thresholds to represent different levels of service (LOS) that are determined during a field inspection of the assets contained in a representative number of samples in each District. At the present time most of these surveys are conducted by District personnel, although research is being done nationally to determine the amount of information that can be obtained using automated methods. Using the criteria established by the agency, a LOS can be calculated by District, Region, shed, foreman, or geographical area. Alternatively, the LOS can be reported on a statewide basis. An example of LOS descriptions used by the Washington State and North Carolina DOTs are provided in table 4. Once the LOS is established, an agency's MMS software can calculate the funding required to raise the LOS for any asset category and the resources required to meet any LOS targets the agency may establish. Some agencies chose to report LOS information in terms of a report card or dashboard. Figure 3 presents an example of a report card for the NCDOT interstate system. The report card shows the average condition by element and/or facility and the overall level of service being provided. Some agencies elect to show the range of values reported in addition to the average condition.

Table 4. Sample LOS descriptions for drainage structures (Zimmerman and Stivers 2007a).

Asset	Performance Measure	LOS Category				
		A	B	C	D	F
Ditches						
Washington	% greater than 50% filled with sediment or debris	0 – 1%	1.1 – 5%	5.1 – 10%	10.1 – 15%	> 15%
North Carolina	Blocked ≥ 50% and not functioning as intended	2%	6%	9%	12%	> 12%
Culverts (or Crossline Pipe)						
Washington	% greater than 50% filled or otherwise deficient	0 - 2%	2.1 – 5%	5.1 – 10%	10.1 – 20%	> 20%
North Carolina	Blocked ≥ 50%, or damaged	1%	3%	4%	6%	> 6%
Slopes						
Washington	% of centerline miles with slides or erosion encroaching on, or undermining the shoulder or traveled way	0 – 2 %	2.1 – 4%	4.1 – 7%	7.1 – 10%	> 10%
North Carolina	Failures ≥ 1 foot wide	1%	2%	4%	6%	> 6%

A more recent development in presenting the results of condition assessments is the dashboard, which summarizes the agency's success at meeting pre-defined performance targets in a visual format (using colors, numbers, and a familiar graphic) that is fairly easy to interpret and is automatically generated each time the user logs onto the system. An example of the dashboard from the Minnesota DOT's web site is presented as figure 4. The dashboard gauges in figure 4 reflect the average number of hours to snow-free lanes for various functional classifications of roads. For example, the expectation for the super commuter routes is between 1 and 3 hours for bare lanes.

Statewide Average - Interstate System

	Level of Service				
Maintenance Activity	+ A -	+ B -	+ C -	+ D -	+ F -
Pavement					
Pavement				■	
Unpaved Shoulders and Ditches					
Low Shoulder			■		
High Shoulder				■	
Lateral Ditches				■	
Drainage					
Crossline Pipe - Blocked					■
Crossline Pipe - Damaged		■			
Curb & Gutter - Blocked		■			
Curb & Gutter - Damaged	■				
Catch Basin & Drop Inlet - Blocked					■
Catch Basin & Drop Inlet - Damaged		■			
Roadside					
Mowing				■	
Brush & Tree Control					■
Litter & Debris				■	
Slope	■				
Guardrail	■				
Traffic Control Devices					
Traffic Signs		■			
Pavement Striping					■
Words & Symbols					■
Pavement Markers					■
Environmental					
Turf Condition					■
Misc. Vegetation Management					■

■ Average Feature Service Level

Figure 3. Sample report card (NCDOT 2006).

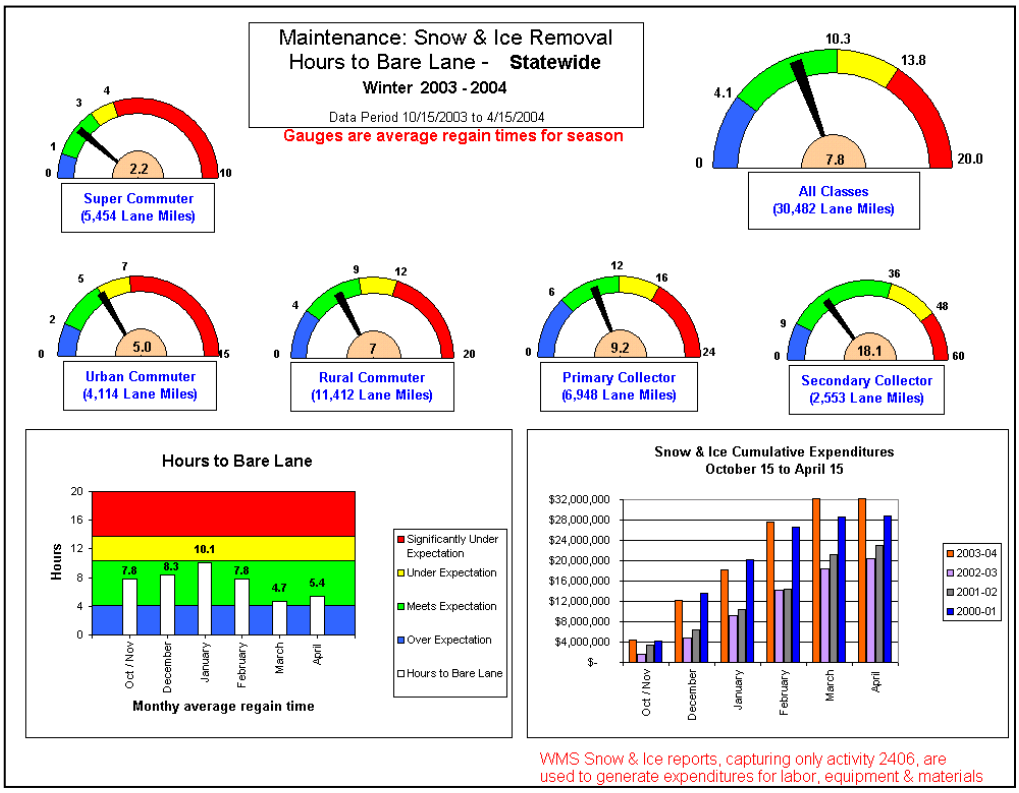

Figure 4. Sample dashboard (Mn/DOT website).

Although performance-based budgeting requires additional work, it provides significant benefit beyond the traditional way of setting maintenance budgets. Using a performance-based budgeting approach, an agency can better assess whether the LOS being provided is adequate or whether resource adjustments are needed to match the agency's priorities. Additionally, senior management is better able to report the consequences associated with changes in maintenance funding. Therefore, agencies can be more responsive to these inquiries and can better communicate their need for funding and/or ability to meet customer expectations.

Some examples of the activities underway in several state highway agencies are provided based on phone interviews with Maintenance personnel. The examples include a SHA (Caltrans) that has had its MMS in place since 2003, another SHA (NCDOT) that has recently completed its implementation, and two SHAs (MDOT and UDOT) that are in the process of implementing new MMS software). In addition, the Requests for Proposals (RFPs) and Requests for Information (RFIs) recently issued by Mississippi DOT, Utah DOT, Alabama DOT, and New Mexico DOT are provided in Appendices B, C, and D. The technical specifications from the Mississippi DOT RFP are included in Appendix B, the entire RFP issued by the Utah DOT is included in Appendix C, and the RFIs issued by the Alabama DOT and New Mexico DOT are included in Appendix D. These latter two documents are combined because they are so much shorter than the Mississippi and Utah RFPs.

California Department of Transportation (Caltrans)

Caltrans' Division of Maintenance completed the implementation of its Integrated Maintenance Management System (IMMS) in June 2003. The system, which was developed by Hansen Infrastructure Technologies in cooperation with Deloitte Consulting, was deployed in 12 District locations and 500 maintenance stations. The system provides access to real-time data, eliminates duplicate data entry, makes it easy to generate reports electronically, and provides a central repository for information at all levels.

North Carolina DOT (NCDOT)

The NCDOT worked on the development of its new AgileAssets MMS over a 3-year period. Procedures for conducting LOS surveys had been completed by the time the new MMS vendor was selected. Under the implementation contract, the vendor first conducted onsite interviews with DOT personnel over a period of about 18 months to learn about and document the existing business processes. Field personnel were brought in to document their work activities and then customized user interfaces were developed. IT was responsible for acceptance testing and system testing of the software. The program was piloted in two Divisions for several months before statewide training began. Although AgileAssets offers modules for fleet and material management, only the maintenance management modules have been implemented.

NCDOT is not accessing its MMS using the web, although they plan to implement the web-based application once they have a plan for addressing security issues. Instead, they use a client server environment that they consider to be slow and clunky. Clerks in each maintenance yard manually enter data into the system. The Department does not currently have T1 lines to each of its maintenance yards.

Mississippi DOT (MDOT)

Earlier this year, MDOT selected Jacobs Carter Burgess to implement the CitiTech Management Software program. The project began in April and is scheduled to be completed in an 18-month period. The first tasks involved the development of a project plan, which is now being expanded to document existing business processes and work flows. The customization of the software is also beginning.

Prior to selecting a software vendor MDOT worked with Dye Management to develop LOS descriptions to assess maintenance quality. It took several months to develop the maintenance assessment process and field personnel were actively involved in the activity to help ensure buy-in to the process. Some changes have already been incorporated into their survey process to make it more statistically sound. Since ITD has already done some preliminary work in the development of LOS guidelines as part of the PRIMO study, the amount of time spent on this item should be able to be minimized.

The MDOT field personnel continue to be involved in the implementation process with each District Maintenance Engineer serving on the Steering Committee along with Information Management personnel. In addition, one Superintendent and one Analyst from each Division have been appointed as change management personnel to help with the system development and to promote the MMS once the implementation is complete. This is a good model for ITD to use as the new MMS is implemented.

Prior to the implementation of its MMS, MDOT had its asset inventories established for pavement, shoulders, mowable acres, and ditches. As the implementation progresses new asset inventories are being developed for other assets.

Remote access is not a problem for MDOT since the Department installed T1 speeds in each office. Access speeds could be an issue in some remote sheds within Idaho, but as long as the internet is accessible, everyone should be able to use the new MMS. When accessibility to high-speed internet access expands to remote sites, speeds can be increased.

Utah DOT (UDOT)

UDOT also recently acquired the AgileAssets Maintenance Manager program, although a live version of the program has not been released yet. There is still some configuration work going on and train-the-trainer sessions are being conducted.

Prior to the implementation of their MMS, UDOT had a MQA process in place that defined LOS for various features. Their feature inventory was established in one region, but it has yet to be established for the rest of the state. UDOT anticipates that each maintenance shed will be responsible for populating the feature inventory using various sources of information and their normal process of conducting maintenance work. Although no priority was placed on any feature type, UDOT recognizes it may have to establish inventory priorities if the workload becomes too great.

Remote access is slow in several stations because they connect through satellites. However, as long as the MMS operates no slower than the Department's existing programs, they do not expect to have performance complaints when they go live with the new MMS. Since the Department is going to be using the web version of the software, it is a priority to upgrade the access to each station. This will be important since each station will enter data on a laptop computer that is checked out when they go in the field. When the crews return to the office, the computer is placed in its docking station and the information is uploaded into the MMS. A desktop computer will also be available at the station and it is expected that most data entry will be done using it since some crews will continue to record information on paper.

UDOT is implementing both the Network Manager and the Maintenance Manager modules of the AgileAssets suite. They are negotiating with AgileAssets to acquire the Pavement Management module to store work activities. The Department currently plans to continue using its dTIMS pavement management software (from Deighton Associates) for pavement management activities. UDOT expects to develop an interface between the dTIMS and the Agile Assets software for work history information.

Interfaces

Several SHAs specifically addressed the interfaces with existing software packages as a requirement under their MMS implementations. Several examples of the approaches taken by these agencies are provided.

- The NCDOT financial management software was being replaced with SAP business software (originally developed by a company called Systems Applications and Products in Data Processing) at the same time the Department was implementing its new MMS. Initially, the Department wanted the MMS to be the source for time sheets, but the timing didn't work out. As a result, SAP became the source for inputting time using work

sheets. The work activities are linked back to the MMS through a unique identifier known as a task number. Each time a daily work assignment is completed, it is assigned a unique task number for recording time, hours, material, and equipment used. The task number links to the location information and cost information in the MMS. Each night SAP is downloaded into the MMS so the maintenance information is kept current.

- The MDOT is developing interfaces between its equipment and financial management systems (provided by KPMG), pavement management, bridge management, and transportation information (GIS). The preliminary design for these interfaces is being developed now by their contractor.
- UDOT had to address issues similar to those in Idaho with its financial management system. Given the constraint that no new fields would be added to the FMS to track data important to the MMS, a new employee has to obtain a unique ID from HR before being able to enter data into the MMS. Payroll is fed using a special database created for this purpose, which is referred to as the *Super Tanker*. Each night a routine is run to exchange information back and forth. UDOT has also established interfaces with about 17 other programs, including the Linear Referencing System, a public site (with common data items), GIS, Pontis (the bridge management system), and Primavera (for scheduling). This approach for meeting the needs of both a financial management system and a MMS appears to be feasible in Idaho, as does the following approach used in Kansas.
- Kansas DOT (KDOT) recently completed the development of a customized program to feed its financial and maintenance management systems. Using a consultant (Quilogy), KDOT defined its business requirements for capturing employee time, equipment, work accomplished, materials, and maintenance project and a database program was established to populate the Department's mainframe MMS. The maintenance project number in the CrewCard database matches tables in other systems that provide the route and route markers associated with the project. Grids for entering regular hours are provided, but special pay factors such as overtime for plowing, military or sick leave, or taking a vehicle home for emergency work are also accommodated. These features are only available for data entry if the associated activity allows those types of entries. Supervisors have access to employee timesheets for approval and timesheets can be signed electronically at each level. The program has been rolled out in half the state and so far they report it is trouble free and easy to use. The Department reportedly spent about $1M developing its package, but since it was developed specifically for them they do not have to pay licensing fees. A separate work order was established for training KDOT crews. The KDOT personnel expressed willingness to demonstrate the package to ITD personnel, should there be any interest.
- The Louisiana Department of Transportation and Development (LADOTD) is in the process of installing AgileAssets' Maintenance Manager. Their interfaces are being outlined at this time, but the Department envisions that maintenance resource information will be entered into the MMS and nightly syncs will be performed to push the information into is financial management system (SAP). At the same time, personnel changes from SAP are uploaded into the MMS so it remains current and it can perform the necessary HR checks as time is entered into the MMS. This approach to interfacing the MMS with a financial management system would be viable in Idaho.

Costs

The following cost information was provided by the agencies contacted by the research team.

- The NCDOT reports that the implementation of the MMS cost approximately $5M to $6M, including maintenance fees and a statewide license (it is estimated that maintenance fees for their software licenses are approximately $300,000 per year). There are several Maintenance folks and IT folks who work on the system full time.
- MDOT reports that the installation of their MMS is expected to cost between $900k to $1.5M. Licenses for 300 users cost approximately $100k to $250k annually. In addition, additional funds were spent on the Dye Management contract, which is on-going to oversee the MMS implementation. These costs were not available.
- UDOT estimates that their one-time cost for the software implementation and licensing is approximately $2M, with about half of the money spent on implementation activities and half spent on licenses. Annual maintenance fees are estimated to be approximately 20 percent of the cost of the software licenses (approximately $200,000).

Summary

There are certain features that are becoming more common in the MMS programs used by SHAs today.

- Web-access to enter and retrieve data.
- Levels of Service for assessing maintenance quality and for setting performance targets.
- Performance-based budgeting tools that link the LOS with budget requirements based on past resource uses.

When asked what suggestions agency personnel might have for Idaho as they move forward with their implementation, the following suggestions were offered:

- If possible, push harder for the MMS to be the source for reporting time information.
- Prepare field personnel with the computer skills needed to operate the system. In some cases, remedial computer classes were needed.
- Have as much field input as possible to help ensure that the software matches the existing business processes and that it has the buy-in of the users.
- Protect against a private company going out of business and losing access to the source code for proprietary software by requiring the source code to be placed in escrow.
- Establish specific performance metrics for operating speed (e.g. 3 seconds to load a screen and 1 second for a popup to appear). UDOT backed off its performance measures and then had nothing to hold the contractor to when performance lagged. They report this is especially important with a web-based version of the program.
- Define the functional requirements as much as possible. Vague functional requirements are hard to enforce.

Pavement Management

Pavement management systems are used by most SHAs to identify and prioritize pavement improvement needs so the most cost-effective strategies can be identified. An effective pavement management system also addresses other agency needs, such as providing the information needed for HPMS reporting, to support the development of long-term plans, and to demonstrate the consequences of different investment levels.

The sophistication of pavement management systems varies depending on factors such as the features provided by the software, the capabilities of the pavement management staff, the degree to which upper management supports pavement management, the location of pavement management within the agency, and the analysis needs of the agency. Agencies considering the implementation of new pavement management software should look for tools that address the agency's needs within any resource constraints that may exist. Ideally, the software will be flexible enough to adapt to changes within the agency's decision processes that may occur over time.

However, the success of a pavement management system is not dependent only on the functionality and flexibility of the pavement management software. The most successful organizations have business processes in place that support its pavement preservation philosophy and help to ensure that the information in the pavement management system continues to address the agency's needs and that information needed by its users is provided on a timely basis. Often agencies forget that pavement management is a tool to help make very complex decisions that have a significant financial impact on the agency. Regardless of the type of pavement management system used, the final project and treatment selection requires sound, engineering input from field personnel.

This section of the report describes the way pavement management operates in several SHAs in the following areas:

- Software.
- Analysis capabilities.
- Organizational issues.
- Costs.

A summary of general observations is also provided.

Software

When asked about future pavement management initiatives, the responses to a 2006/07 survey of pavement management practice conducted by the FHWA indicates that 15 agencies had plans to upgrade their software or to redesign their existing systems (Saadatmand 2008). There are four primary providers of pavement management software within SHAs. In addition, one vendor has been working with the Florida Turnpike to provide pavement management services. These vendors are listed in table 5.

According to a separate survey of state practice conducted in 2005 by Applied Pavement Technology with 38 states responding, 17 states reported that they developed their pavement management systems inhouse, 11 reported that they are using Deighton's software, 5 agencies reported they are using AgileAssets' software, 4 reported using Stantec's software, and 2

reported using some other product. Most agencies that have developed systems inhouse did so many years ago before vendors were able to customize their software products as much as they can today. Therefore, there are few recent examples of agencies develop pavement management systems inhouse.

Virginia recently released an RFP for new pavement management software. A copy of the RFP they developed is included in Appendix E. The process resulted in the selection of the Agile Assets pavement management software.

It should be noted that there is only one vendor listed in tables 3 and 5 that provides both MMS and PMS software. This vendor, Agile Assets, began in the software development business with its pavement management system. The development of its MMS has been more recent. However, several states have taken advantage of these linked systems in the past few years and have implemented both systems. The North Carolina, Kentucky, and Wyoming DOTs have all acquired licenses for both programs. The Utah DOT is in the process of acquiring the Agile Assets PMS, but plans to continue to use its dTIMS software (from Deighton and Associates) for its network-level pavement management analysis.

Acquiring maintenance management and pavement management software from the same vendor virtually assures the agency that the two systems are compatible. However, other state highway agencies successfully use software from different vendors for maintenance management and pavement management activities (including the Kansas and Utah DOTs). This is not a problem because there is a limited amount of interactivity required between the two programs. However, to be successful the two systems should use the same linear referencing system and maintenance activities should be able to be related to pavement management sections (through the GIS). If GPS units are used to record maintenance locations, this simplifies the process of linking section information. Then, maintenance activities can be reported by pavement management section to assist in making project and treatment decisions. Similarly, the pavement management system can provide District personnel with reports that list candidate projects for preventive maintenance that can be used to develop annual maintenance plans.

Analytical Capabilities

Pavement management systems vary in the types of condition information collected, the use of the condition information in developing condition indexes, and the way the information is used to support decisions. Most SHAs collect rutting, roughness, and cracking information on the pavement network every 1 to 3 years (often depending on functional class). In most instances, cracking is differentiated by type of crack so that at a minimum, load-related cracking and non-load related cracking are differentiated. The information is used to calculate one or more pavement condition indexes, which can be used to report overall conditions and to identify appropriate types of rehabilitation. Most SHAs use individual condition indexes (such as a structural cracking index, a miscellaneous cracking index, and a roughness index) for treatment selection and a composite index for reporting overall network conditions. Some SHAs (such as Minnesota DOT) uses raw distress information to identify appropriate treatments. ITD currently defines deficiencies in terms of its cracking and roughness indices. More detailed distress data (including crack type, severity, and extent) are collected as part of ITD's pavement management survey, but the information is not used by the Division of Transportation Planning to determine treatment recommendations.

Table 5. Pavement management vendors with state highway (or equivalent) experience.

Vendor	Address	Software Product	Sample Client List
AgileAssets	2602 Dellana Lane Austin, TX 78746-5746 www.agileassets.com	Pavement Manager	Wyoming DOT North Carolina DOT Montana DOT Oregon DOT
Deighton & Associates, LTD	112 King St. E Bowmanville, Ontario L1C 1N5 Canada www.deighton.com	dTIMS CT	Colorado DOT Indiana DOT Utah DOT Iowa DOT
Stantec Consulting	2810 N. Parham Road, Suite 242 Richmond, VA 23294 www.stantec.com	HPMA	Minnesota DOT Arizona DOT
Axiom Decision Systems	5146 Dorsey Hall Drive, Suite 202 Ellicott City, MD 21042 www.axiomds.com	Axiom Infrastructure Manager (AIM)	Maryland State Highway Administration
Applied Research Associates	100 Trade Center Drive, Suite 200 Champaign, IL 61820 www.ara.com	RoadCare	Florida Turnpike

There are several types of analysis models that are incorporated into a pavement management system for predicting future conditions, determining feasible treatments, estimating treatment costs, and forecasting network conditions after a set of projects has been selected. For instance, pavement performance models are used to predict future pavement conditions with and without anticipated treatments that may be applied. They are typically built using a statistical analysis of historical pavement condition information and average rates of deterioration are established using factors such as pavement type and functional classification. The Division of Transportation Planning reported that they are developing probabilistic performance models at this point in time. Models that predict changes in the Roughness Index are built into the HERS-ST program used by the Division of Transportation Planning and performance models are also incorporated into the District 6 pavement management tool.

To determine which treatments are feasible under different funding scenarios, it is important that the pavement management system have treatment rules that define the set of conditions that should exist for each treatment to be considered. Included with the treatment rules is financial information so the cost of each feasible treatment can be estimated. Treatment rules should reflect the policies and practices of the agency that will be using the information. Therefore, the information should be reviewed regularly as agency practices change or as new technology, materials, and designs are developed. The pavement management system used by the Division of Transportation Planning has very general treatment rules since the system is geared more towards repairing only pavements that are defined as being deficient. Alternate treatment

strategies, such as strategies that make use of preventive maintenance treatments, are not incorporated into the existing network-level tool.

In addition to defining the conditions under which each treatment is considered feasible, an agency should develop impact rules that define the change in pavement condition, surface type, and rate of deterioration associated with each treatment considered in the analysis. The impact rules are important for the agency to compare future conditions under different programming scenarios.

One of the most valuable features of a pavement management system is its ability to quickly determine the impacts of different maintenance and rehabilitation programs and/or different investment strategies on future pavement conditions. This type of analysis requires an optimization routine that can evaluate the cost-effectiveness of various options using anticipated funding constraints so the agency can determine the strategy that best fits its objectives. Many pavement management systems use an incremental benefit cost (or marginal cost-effectiveness) routine to optimize the use of available funds. Less sophisticated pavement management systems utilize a simple ranking technique to prioritize maintenance and rehabilitation needs that may not result in an optimal program. Therefore, it is recommended that a pavement management system provide more than a ranking technique if determining the most cost-effective program is important to the agency.

Since the existing ITD pavement management system evaluates only deficient pavements, it has not needed the optimization tools currently available in today's pavement management systems. There is an optimization routine built into the HERS-ST program, but it only optimizes expenditures on highways once a need has been defined. Therefore, for ITD to evaluate the cost-effectiveness of different treatment strategies and to determine the best use of available dollars, software with at least incremental benefit cost tools is needed.

The recommendations from the pavement management system are used by the transportation agency to develop improvement programs for capital and maintenance projects. In its survey of state practice, the FHWA reports that a total of 44 out of 52 SHAs (the District of Columbia and Puerto Rico were included in the survey) use their pavement management system to produce a list of recommended candidate projects (Saadatmand 2008). Most agencies use a combination of worst first (where the pavements in worst condition are the highest priority for funding) and multi-year prioritization (where the cost-effectiveness of each project is considered in determining what projects should be funded). Interestingly, only 16 agencies indicated that pavement management information is used for long-range transportation planning (Saadatmand 2008). More common is the use of pavement management for developing Statewide Transportation Improvement Programs and Pavement Preservation Programs. Without access to the survey results, the research team can not say with confidence what responses were provided for Idaho. However, based on the research team's knowledge of the existing system, we would expect that the Idaho response indicates that the pavement management system is being used to recommend candidate projects and for long-range transportation planning.

The results of a pavement management analysis are used to communicate with upper management and politicians the need for additional funding and/or to measure the agency's progress towards performance targets or goals for the highway network. Although a pavement management system uses pavement condition indexes for identifying and prioritizing maintenance and rehabilitation needs, the information is typically too technical to report to upper level decision makers. For that reason, there are a number of other methods of reporting network

conditions that have been used effectively. For instance, some agencies use a subjective rating of Good/Fair/Poor to report the percent of the network in each condition category. Others report the number of vehicle miles traveled on good roads. This measure reflects the volume of traffic driving on good roads, which may be more important than the total number of miles of good roads in urban areas. Unfunded needs and/or backlog are also terms that have been used to report changes in network conditions. As the name implies, unfunded needs (or backlog) represent the cost to repair streets that have not been programmed due to funding constraints or other factors. Backlog may also be reported in terms of miles rather than cost. ITD's reporting of deficient roads is an example of effectively simplifying the reporting of pavement condition information.

In recent years there has been an increase in the use of Remaining Service Life (RSL) as a measure of network conditions due to the FHWA's support. Very simply, the average RSL of a network reflects the number of years before an unsatisfactory condition is reached. The RSL is calculated for each pavement section using the agency's pavement performance models and an average RSL, or weighted average RSL, is calculated for the entire network. One of the challenges to the use of RSL as a reporting tool lies in communicating what an RSL of 0 actually means. Since pavement failures are typically not catastrophic in nature, vehicles can travel on roads that have a RSL of 0 for several years. This concept can be confusing to individuals who are not familiar with the pavement management system.

Earlier this year, a Pavement Management Peer Exchange was conducted to showcase the use of pavement management to support agency decisions within the Minnesota and Utah DOTs. A description of their use of pavement management information to support project and treatment selection decisions is provided. This information has been extracted from the final report for the Peer Exchanges (Zimmerman 2008).

Minnesota DOT (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 Stantec's 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 great deal of 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.

Mn/DOT's pavement management software is used to evaluate preventive maintenance, rehabilitation, and reconstruction alternatives for each section in the database. The treatments listed in table 6 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. 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.

Table 6. 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.

As a decentralized state, the Districts are heavily involved in the selection of projects and treatments. In a typical analysis, the final list of projects is imported into the pavement management system and future conditions are generated in terms of performance measures. Where the projected condition does not meet the State's strategic performance targets, adjustments are made to the program or additional funding needs are estimated and reported. Preventive maintenance projects are programmed separately since the Statewide Transportation Improvement Program (STIP) lists a total funding level for preventive maintenance rather than listing 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 (where the Pavement Management Unit is based) 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.

Utah DOT (UDOT)

UDOT's pavement management system is housed within the Division of Asset Management, which falls under Systems Transportation Planning. Primary responsibilities for the Division 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.

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 dTIMS pavement management system. 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.

A variety of treatment types are considered in the pavement management analysis, as shown in table 7. The Department continues to work on refining the rules for selecting each treatment, with current efforts focused on improving the PCC treatment rules.

Table 7. 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) used on sections with less than 7,000 vehicles per day (vpd) Medium seal (such as microsurfacing or a hot-applied chip seal) used on sections with more than 7,000 but less than 15,000 vpd High seal (such as an open-graded surface or a Nova Chip) used on sections with more than 15,000 vpd 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

In general, seal coats are applied to pavements in good condition with indexes between 70 and 100. 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.

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.

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.

Reports from the pavement management system are 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.

Organizational Issues

The ITD's existing pavement management system is located within the Division of Transportation Planning. As a result, the software meets most of the reporting requirements for Planning and also provides pavement condition information for use by the Division of Highways as STIPs are developed.

Pavement management can be successful under almost any organizational structure, as long as the needs of the various users are addressed. As shown in figure 5, the FHWA's 2006/07 survey of state practice indicates that the most common location for pavement management is in the Materials Division, although a significant number of agencies have pavement management housed in either a Pavement Division or Planning Division. Two agencies have established Asset Management Divisions to house pavement management.

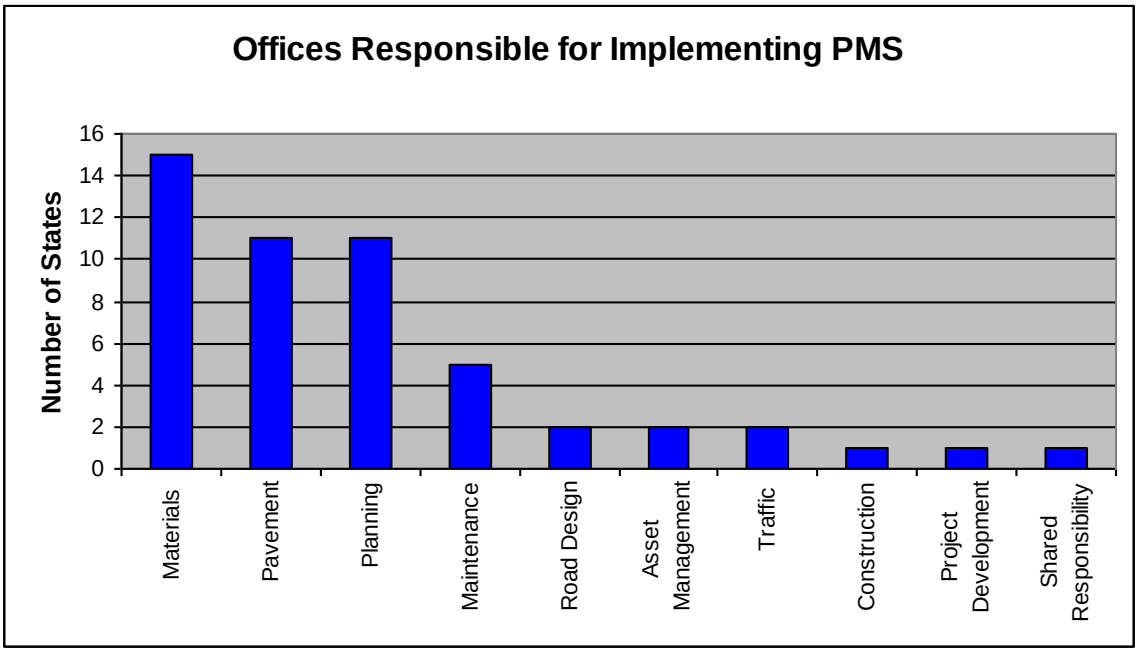

Figure 5. Location of pavement management in state highway agencies (Saadatmand 2008).

The amount of information that can be collected and analyzed by the pavement management staff varies depending on the number of personnel dedicated to these activities. Out of 25 SHAs with five or less personnel assigned to pavement management, 13 of them rely on these individuals to collect pavement condition information and develop improvement recommendations. In the other 12 agencies, the pavement condition data collection may be outsourced because of the size of the Department. Approximately 12 agencies have between 5 and 10 people dedicated to pavement management (Saadatmand 2008). ITD collects its own pavement condition information even though there are fewer than 5 full-time equivalents working on pavement management within the Division of Transportation Planning.

Interfaces

A pavement management system relies on the availability of quality information about the pavement network to make reasonable project and treatment recommendations. In an agency the size and complexity of a SHA, some data may be stored in the pavement management database, but other information is extracted from other existing sources of information. As a general rule, information that is needed by a number of users is stored in a database that is accessible by each group. Information that is needed to run the pavement management analysis can be extracted from these central data sources or stored within the pavement management system, if the data are not accessed by others.

In the 2005 survey of state practice conducted by Applied Pavement Technology, pavement management engineers were asked to identify the data elements that are stored in the pavement management database and those that are stored in a database external to pavement management and imported for the analysis. Where data are stored external to the pavement management system, interfaces must be developed. The results from the survey are presented in figures 6 and 7. Note that some agencies store the information in more than one location, so the total responses for each data element are not necessarily equal.

A review of the data shows that the data elements used almost exclusively for the pavement management analysis, such as current treatment strategies, treatment costs, treatment triggers, and prioritization factors, are stored in the pavement management system. Secondly, information such as current and historical road conditions is primarily stored in the pavement management system, but a number of agencies report that this information is also stored in an external database. More general road information, such as highway inventory, road geometrics, traffic, design, and construction status, are primarily stored in an external database. This is probably to maximize accessibility to the data since it is important to a number of users. A few of the data elements listed in the questionnaire, such as weather/environment and the implemented design strategy, do not appear to be used by many agencies.

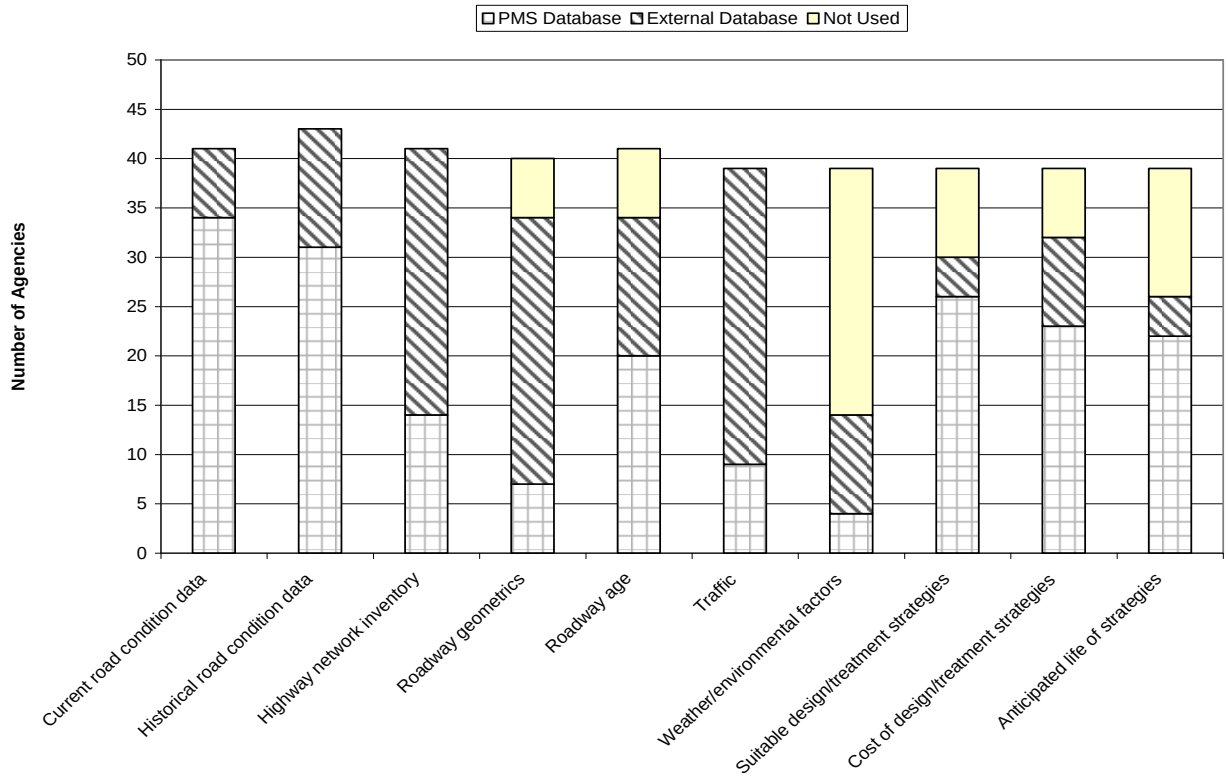

Figure 6. Data storage location of data elements used in pavement management – part 1 (Zimmerman 2005).

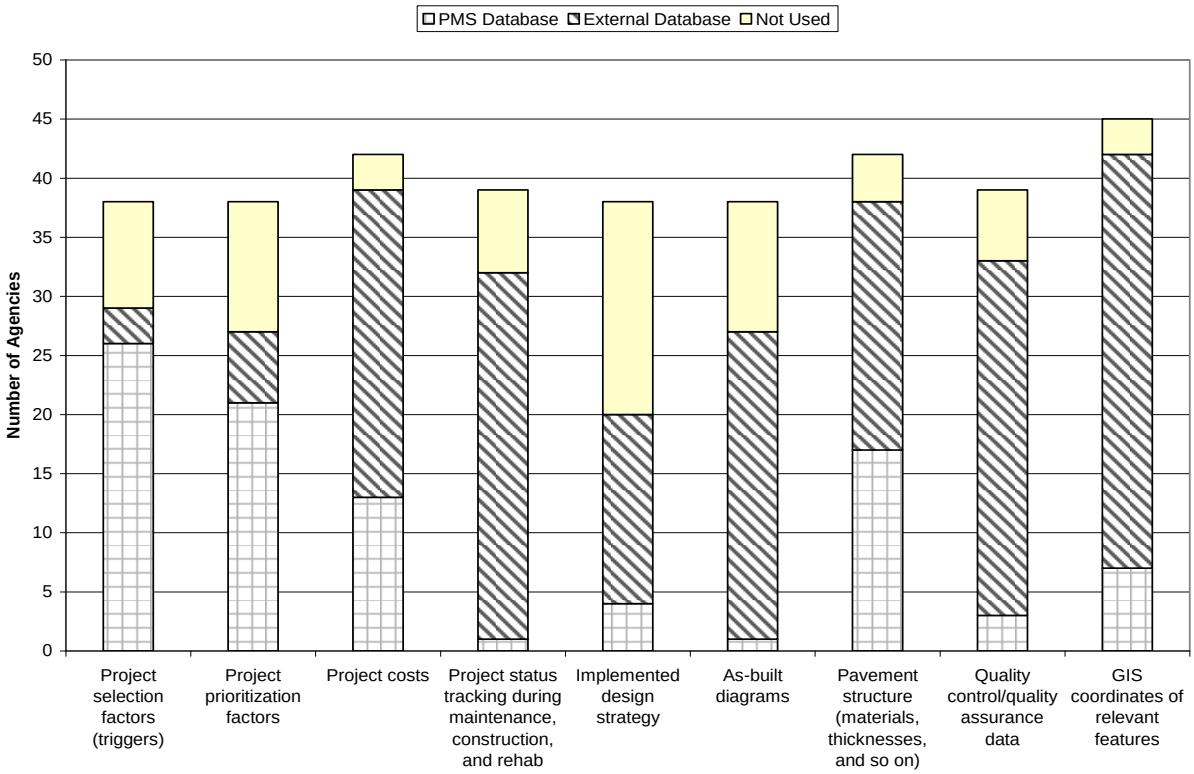

Figure 7. Data storage location of data elements used in pavement management – part 2.

Costs

As part of the 2005 survey of state practice, APTech also asked participants to report costs associated with hardware and software acquisitions to support pavement management, implementation costs (including staff and consultants), continuing software maintenance and license fees, and continuing operation of the system. Since a limited number of agencies were able to provide this information, all of the information provided is summarized in table 8. No agency names are provided, but each row represents the data provided by one responding agency. Interestingly, only one agency that developed a system in-house provided cost data when responding to the survey. Information that was not provided by the respondents is noted as a $0 expense in the table.

Table 8. Pavement management costs (Zimmerman 2005).

In-House or Vendor Supplied Software	Software	Hardware	Implementation Services	Continuing Software Maintenance and Licenses	Continuing Operations and Maintenance
Vendor	$50,000	$10,000	$0	$3,000	$0
Vendor	$500,000	$20,000 to $30,000 for computers	Included with software	$15,600	$360,000 for data collection plus 11 staff
Vendor	$75,000	$0	$150,000	$4,800	$150,000
Vendor	$15,000	$0	$2,000,000	$3,000/year	$450,000/year (includes $300,000 for data collection annually)
Vendor	$750,000 over 20 years	$100,000 over 20 years	$250,000 over 20 years	$5,000/year	$50,000/year
Vendor	$200,000	$0	$0	$40,000	$0
Vendor	$90,000	$1,000,000 (includes ARAN van)	$100,000/year	$20,000/year	$0
Vendor	$120,000 for upgrade to Windows	$0	$0	$0	$20,000 every 4 to 5 years for changes
Vendor	$25,000	$0	$5,000	$11,000	$0
Vendor	$400,000 in 1996	$0	$0	$120,000 in 2003	$24,000/year
Vendor	$250,000	$0	$0	$0	$100,000/year
Vendor	$315,560	$0	$0	$25,200/year	$0
Vendor	$35,000 for 1st license; $11,000 for subsequent licenses	$0	$235,000 plus more services in later years	$1,400 per year per license	$500,000/year
Vendor	$1,500,000	$750,000	$0	$50,000/year	$1,000,000
Vendor	$80,000	$64,000	$236,000	$50,000/year	$1,300/year
Vendor	$30,000	$7,000	$180.000	$15,000	$0
In-house	$0	$0	$400,000 over 8 years for staff; $250,000 over 8 years for consultants	$0	$900,000/year including data collection

Summary

There are certain features that are becoming more common in the pavement management programs used by SHAs today.

- The most common use of pavement management results is the identification of feasible projects and treatments to help agencies make effective use of available dollars. These systems can also be used to report network conditions and to identify needs for planning purposes, but a primary use is as a programming tool to assist District personnel. This is a somewhat different focus than ITD's current pavement management program, which is primarily used as a planning tool. The pavement management tool used by District 6 more closely matches this application.
- A number of agencies are developing stronger links between pavement management and maintenance management by implementing software from the same vendor. Examples include the North Carolina, Utah, and Wyoming DOTs.
- A broad range of treatments are considered in most pavement management systems, ranging from reconstruction and rehabilitation to preventive maintenance treatments. A number of agencies are developing strategies for enhancing their systems to better support their pavement preservation programs. The ITD's current pavement management system does not adequately address strategies that include intervention before a pavement section is classified as a need.

CHAPTER 5.0 – IMPLEMENTATION APPROACHES

The previous chapter illustrates the diversity of approaches that SHAs have used to implement maintenance management and pavement management systems. Because of the range of options available to ITD, several implementation approaches are included in this section of the report. In Chapter 6, recommended strategies are provided.

An overall framework for the implementation of management systems is presented in the *Guidelines for Enhanced Maintenance Management Systems* and replicated in figure 8. As the figure shows, the foundation of good practice relies on basic system capabilities that support budgeting, planning, and monitoring activities. Agencies that have progressed to the second level have developed methods of assessing asset condition and have individual management systems in place to support the budgeting and planning activities. Higher levels in the pyramid reflect budget models that are linked to performance measures, the integration of individual management systems (often using GIS), and tools to perform investment trade-off decisions between assets and investment options.

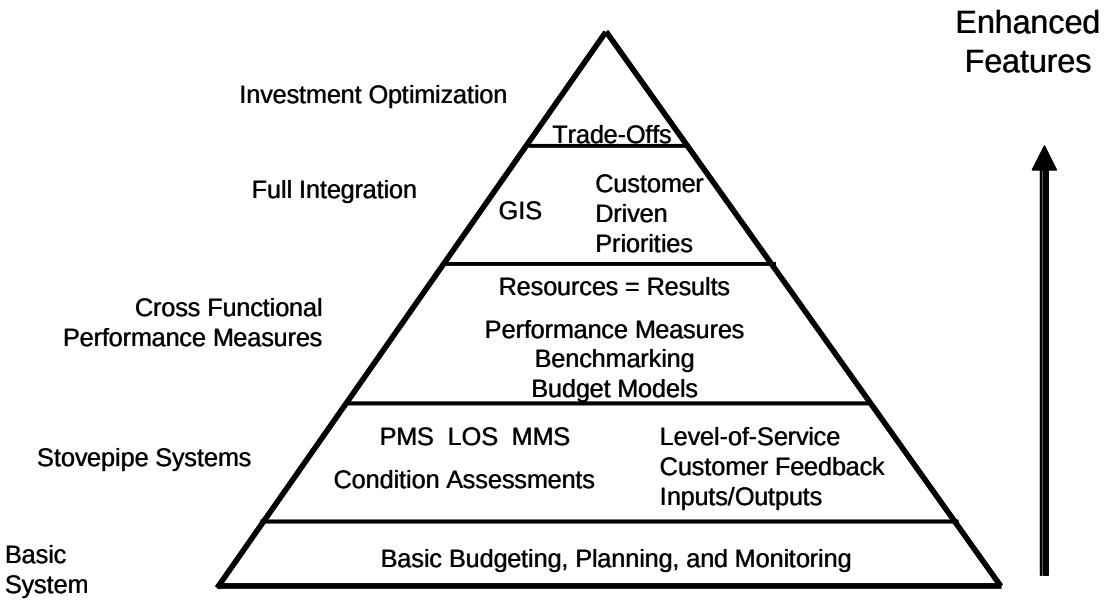

Figure 8. Asset management implementation stages.

According to the implementation pyramid, ITD is at the basic level in terms of its maintenance management capabilities and the second level in terms of pavement management. The implementation approaches presented in this chapter identify the various activities that should be undertaken to raise the Department's maintenance management capabilities one, two, or three levels. The pavement management options describe enhancements needed at the current level of operation, but also include options for moving up the pyramid at least one level to consider alternate preservation strategies and to enhance its ability to predict future conditions.

Maintenance Management Options

The participants in the interviews to determine the Department's needs made it clear that the basic cost accounting functions provided in the old MMS are sorely missed. As a result of their absence, it is difficult for upper management to describe consequences associated with changes in maintenance expenditures, maintenance logs are prepared manually in diaries (so information is difficult to find and compile), and it is no longer possible to evaluate and track productivity. Therefore, the basic implementation option for maintenance management includes the implementation of MMS software to provide this capability. The moderate implementation option uses the same MMS software, but provides for the use of LOS for the primary assets maintained by the Department for performance-based budgeting. It relies on the LOS definitions developed as part of Cambridge Systematics' PRIMO project as a first step in assessing maintenance quality. The highest implementation option expands on the use of LOS and focuses on a fully integrated system that interfaces with pavement management to better optimize the Department's use of preservation funding. Each of these three options is described in more detail in the following sections. Along with the descriptions is a summary of activities that will need to be done in conjunction with the implementation of the software and a table that illustrates which of the defined needs will be addressed with each implementation option.

Option 1: Basic MMS Implementation Option

Under this option, ITD will license and implement a MMS from a commercial vendor to record maintenance activity information by location. Although the software will have the ability to conduct performance-based budgeting activities, at this level it is not recommended that these features be implemented immediately. Instead, these features can be added in the future after the initial cost accounting features are in place (see options 2 and 3). The basic option will provide the following features:

- Cost accounting information by activity and location.
- The ability to analyze productivity at all levels (statewide, district, foreman, shed).
- The ability to estimate budget requirements based on historical trends.
- The ability to recover and track both inhouse costs and contracted cost activities.
- Preparation of work orders and contract development to track daily activities.
- A single point of entry for maintenance information.
- Remote access to enter or retrieve information.
- The ability to add or remove assets from the system.
- Standard and customized reporting features.

For the MMS to operate successfully, an interface with the Department's Advantage Financial Management System will have to be developed to record the information that is required within the MMS but not provided for in the FMS. Under this approach, an interface similar to that developed by the North Carolina, Kansas, or Louisiana DOT will have to be developed. There are two primary approaches for meeting this need. The Kansas DOT model uses a separate CrewCard program that is used to enter time, material, equipment, and work activity information. CrewCard is linked to existing tables that provide the location referencing information used to report the data. CrewCard is also linked to the FMS to obtain HR information. The second approach is modeled after the Utah DOT, which uses its MMS to enter

work activity information (including time and resource information). Nightly syncs with their FMS push information both directions so payroll information is not delayed and new employees are able to enter information in the MMS within 24 hours of being entered into the system. This last approach is reported to be similar to the approach used by the Wyoming DOT when it implemented its MMS and established its interface with Advantage, but this information was not able to be confirmed by the research team.

Training is also very important to the success of the implementation. Field personnel should be involved in designing the user interfaces and documenting the existing business processes. They should be trained in the operation of the MMS and the use of the information for making decisions.

The estimated cost of implementing this option is presented in table 9. This option includes a statewide license for the MMS software, the development of a customized interface with the Advantage program for payroll, several handheld data collection devices with GPS functionality in each District (approximately 8 to 10 units in each District to share among crews), and support services to customize the software and to conduct training. Annual maintenance costs associated with the statewide license are estimated at $300,000.

Table 9. Costs associated with implementing the **basic MMS option**.

Activity	Estimated Cost	Comments
Statewide software license and implementation	$1,500,000	These costs include software licenses and the cost of developing interfaces to existing data sources, with the exception of the financial management system (Advantage)
Financial management system interface development	$500,000	These costs assume a fully-customized interface will be developed for ITD between Advantage and its new MMS
Hardware	$300,000	These costs provide funding to acquire GPS units for maintenance vehicles.
Customization	$250,000	Within the software, there are opportunities to customize user interfaces to meet the needs of the agency
Training	$150,000	Utah DOT used its vendor to conduct train-the-trainer sessions so most training of field personnel is done internally
Total – One Time Cost	***$2,700,000***	
Annual maintenance	$300,000	Utah DOT reports that annual maintenance costs are approximately 20 percent of the cost of software licenses

Option 2: Intermediate MMS Implementation Option

The intermediate option builds on the basic features by adding the Maintenance Quality Assurance component for the principal assets being maintained by the Department, such as pavements, bridges, signs, drainage features, and guardrails. Inherent to this implementation option is the development and adoption of a method of assessing LOS, which can be used to monitor maintenance quality, establish performance targets, and conduct performance-based

budgeting. The option assumes that a statistically representative number of sample units will be identified in each District for purposes of assessing maintenance quality and that the surveys will be conducted by District personnel. Because not all features will be included in the initial MQA surveys, performance targets and performance-based budgeting will be limited to the selected features, requiring the other features to be budgeted with another method. The same MMS tools recommended under option 1 will satisfy the analysis requirements for this option, but additional feature inventories need to be established and outside assistance may be needed to help finalize the LOS descriptions and inspection methodology. For example, the asset inventories will require that interfaces be established between existing sources of data, including pavement management, bridge management, statewide communications, equipment, and the various spreadsheets containing this information. Asset locations will be spatially located using Global Positioning Satellites (GPS) units installed in each maintenance vehicle (although this feature is not required).

There are several considerations that will help the Department successfully implement this option. First, its previous efforts under the PRIMO project resulted in some initial work in developing LOS. This information, plus information from other SHAs (such as Washington State and North Carolina DOT) can provide the basis for the MQA surveys. Secondly, the Department can begin this process with its most significant assets and build its complete feature inventories over time. Since it is likely that there are a few feature categories that consume most of the resources, it makes sense to begin its efforts with these activities. Training is again important to include in this option, both in developing the methodology and ensuring that it is implemented consistently on a statewide basis.

The intermediate option adds the following features to those described under the basic option:

- A features inventory for the Department's most significant features.
- A Maintenance Quality Assurance process for assessing current Levels of Service.
- The ability to set performance targets on the selected features.
- The ability to conduct performance-based budgeting on the selected features.
- The ability to demonstrate the consequences of budget adjustments on LOS on the selected features.

The additional costs associated with this option are presented in table 10.

Option 3: Highest MMS Implementation Option

Ultimately, ITD will have a MMS that contains a comprehensive features database and represents the full compliment of maintenance activities being conducted by state and contract forces. The information will be accessible through the Department's GIS and location referencing will be provided using GPS units installed in each maintenance vehicle. The MMS will interface directly with the Department's pavement management system to help coordinate maintenance activities with capital improvements and to fully support the Department's pavement preservation program (which is discussed in the pavement management implementation options).

Table 10. Additional costs associated with implementing the **intermediate MMS option**.

Activity	Estimated Cost	Comments
Feature inventories establishment and interfaces	$500,000	
Training	$150,000	
Consulting services – final MQA methodology and LOS	$400,000	These costs reflect the work required to finalize the LOS definitions and to develop a statistically valid survey procedure. The costs associated with conducting the survey, which is expected to be done by ITD District personnel, are not included
Total – One Time Cost	***$1,050,000***	
GPS equipment (not required, but suggested)	$2,000,000	Optional GPS units for each vehicle in the fleet at approximately $3,000 to $5,000 per unit. These units may be added over time as vehicles in the fleet are replaced

To achieve this level of accomplishment, additional feature inventories will have to be established as will corresponding LOS measures. It is assumed that the Department's GIS will utilize spatially located references (under a separate project not included in this cost estimate) and that both ascending and descending directions will be represented. Interfaces will also need to be established with systems outside of the Department, including the Idaho State Police and the Department of Environmental Quality.

At this level, several additional capabilities will be provided to the Department, including those listed below.

- Integration with pavement management.
- Expanded features inventories to include assets not previously included (e.g., light structures, landscaping, buildings, and maintenance yards).
- Integration with other ITD systems (e.g. such as Equipment Management) as sources of feature inventories.
- GIS interfaces for entering data, displaying information, and generating reports.
- Links with ITD video log.

The additional costs associated with implementing this option are presented in table 11.

MMS Summary

Table 12 presents a summary of how each of the three options presented in this section address the needs identified in Chapter 2.

Table 11. Additional costs associated with implementing the **highest MMS option**.

Activity	Estimated Cost	Comments
Feature inventory development	$250,000	It is expected that the inventory information will be collected by ITD field personnel so those costs are not listed. These costs include costs associated with developing the data tables in the MMS
System interfaces	$450,000	
Consulting services and training	$250,000	Consulting services are needed to help define the inventory data and to train ITD personnel to collect the data
Total – One Time Cost	***$950,000***	

Table 12. MMS implementation option summary.

Level of Importance	Feature Category	Identified Need	Description	Degree to Which Currently Addressed	Degree to Which Need Is Addressed (B) Basic (I) Intermediate (H) Highest
High	Data needs	Compatibility with Advantage	The payroll process requires that certain types of HR checks be conducted in real time as data are being entered so paychecks can be issued on time. The MMS needs more detailed information than is required for payroll purposes. Both needs should be addressed.	Low	B,I,H
High	Data needs	Data quality checks	Decisions will be based on the information contained in the MMS. Therefore, it is important that the data are accurate and timely.	Low	B,I,H
High	Data needs	Daily maintenance diaries	In the absence of a MMS, daily activities are reported manually in the foreman's maintenance diary.	Low	B,I,H
High	Information & reporting needs	Video Log Displays of MMS Information	Users intend to view video displays of various features while viewing MMS data. This also allows foremen to discuss problem areas with District or HQ personnel.	Low	B,I,H
High	Information & reporting needs	Basic cost accounting information	Critical information includes the type of work accomplished, the date the work was accomplished, the work location, and the resources (equipment, materials, and labor) used.	Low	B,I,H
High	Information & reporting needs	Historical work activities	Reports showing the number of years (or months or days) that have passed since work was last performed.	Low	B,I,H
High	Information & reporting needs	Statewide access to data and reporting	The software will be used concurrently by users in disparate locations, including HQ, District offices, and sheds. It should be easy to use and flexible enough to respond to different levels of use.	Low	B,I,H
High	Information & reporting needs	Disaster and damage recovery reporting	Reports summarizing the amount spent on disaster or damage recovery will be used by Budget and Finance to request reimbursement from FEMA, insurance companies, or other sources.	Low	B,I,H
High	Information & reporting needs	Routine reports	Routine reports will be needed at the State, District, region, foreman, or shed levels. These will include reports that are run regularly, such as historical productivity rates, budgeted versus actual expenditures, planned and scheduled maintenance activities, frequency of maintenance work on a particular asset, and so on.	Low	B,I,H
High	Analytical functionality	Productivity rate analysis	Basic cost accounting data to track productivity reports at various levels within the Department.	Moderate	B,I,H
High	Analytical functionality	HQ analyses	At this level, the MMS will be used to determine productivity rates, cost-effectiveness of different activities and work sources, future funding needs, return on investment for maintenance expenditures, costs required to raise the LOS, and resource requirements for new assets.	Low	I,H
High	Analytical functionality	District analyses	At this level, the MMS will be used to determine work accomplishments, plan and schedule maintenance activities, determine changes in work crew efficiencies, compare historical trends, establish funding needs, determine material requirements, and identify strategies for budget adjustments.	Low	B,I,H

Table 12. MMS implementation option summary (continued).

Level of Importance	Feature Category	Identified Need	Description	Degree to Which Currently Addressed	Degree to Which Need Is Addressed (B) Basic (I) Intermediate (H) Highest
High	Interfaces with existing systems	Financial management interface requirements	There are special requirements for interfacing with Advantage that may require changes to existing processes to meet the demands of both systems. HR checks need to be performed without slowing down the payroll process, electronic signatures should be obtained on timesheets, future changes to payroll should be accounted for, and time should be entered in minutes. The MMS needs more detail than is currently being reported, the coding system in Advantage needs to be preserved (or a conversion developed), location and activity information should be added, MMS equipment and material entries should be converted to costs, and a process is needed for charging out pooled equipment.	Low	B,I,H
High	Interfaces with existing systems	GASB-34 reporting requirements	A process is needed so maintenance activities, activity date, and work type is available for GASB-34 reporting prior to the close of each fiscal year.	Low	B,I,H
High	Other needs	User-friendly	The user interfaces should be easy to use, information should be displayed graphically, and an easy query function should be available.	Low	B,I,H
High	Other needs	Training	In addition to learning how to operate the software, field personnel need training so they understand the importance of the data they input and how to use the data in decision making. Training should be on-going to refresh skills and to train new crew members. Training is also needed by HQ personnel so they understand the operation of the software and the type of information it can produce.	Low	B,I
High	Other needs	Long-term maintenance plan	The implementation of a MMS needs IT support to help ensure the long-term viability of the system. An oversight team could also be used to review the needs and to set the direction for the implementation.	Low	B,I,H
High	Other needs	System flexibility	The Department operates in an environment that constantly changes. Therefore, the system should be flexible enough to adapt to changes in policies, practices, or procedures.	Low	B,I,H
High	Interfaces with existing systems	Internal and external interfaces	Examples of the types of interfaces that will be required are provided in the summary of needs. Through the interview process, approximately 17 interfaces were identified in the previous section of the report (see page 14).	Low	I,H
High	Information & reporting needs	GIS Displays	There are a number of useful GIS displays that could be developed. For instance, users can display areas with unusually high maintenance expenditures.	Moderate	H
High	Information & reporting needs	GASB-34 reports	Each year the Department reports on the level of pavement maintenance provided. Therefore, Budget and Finance need information on where maintenance activities have been completed.	Moderate	B,I, H
Moderate	Data needs	Single point of data entry	Data entry requirements for the MMS should not duplicate data already being entered into another system. Ideally, maintenance activity data are entered in a computer in the field and uploaded into the MMS when the crews return to the office. There are other techniques that could be used to address this need, such as entering data via portals.	Low	B,I,H

Table 12. MMS implementation option summary (continued).

Level of Importance	Feature Category	Identified Need	Description	Degree to Which Currently Addressed	Degree to Which Need Is Addressed (B) Basic (I) Intermediate (H) Highest
Moderate	Data needs	Supplemental data provided through interfaces with other data sources	A number of interfaces that need to be established are documented elsewhere in this table. There are several sources of information (such as the Department's crash database, the Idaho State Police, wildlife, and Statewide Communications) that provide information to support MMS decisions.	Low	I,H
Moderate	Data needs	Feature inventories	To perform budgeting activities, it is important to have feature inventories in place that track feature type and location (at a minimum).	Moderate	I,H
Moderate	Data needs	Actual cost data	In the past, average cost rates were used for labor, equipment, and material costs. Due to regional differences in costs, it is important that more accurate cost information be used in the MMS.	Low	B,I,H
Moderate	Data needs	Independent of service provider	Work activities conducted by contract forces, state forces, or inmate labor should be incorporated into the MMS.	Low	B,I,H
Moderate	Data needs	Import/export capabilities	It will be important to be able to import and export data from sources both inside and outside the Department.	Low	I,H
Moderate	Information & reporting needs	Transparent access to data	Data table structures and access to information should be provided for generating queries, linking the MMS to new systems, or writing applications.	Low	B,I,H
Moderate	Information & reporting needs	Total project cost reporting	Since some projects are made up of multiple activities, it is important that they be able to be combined to get total project costs.	Low	B,I,H
Moderate	Analytical functionality	Planning and budgeting analysis	In addition to reporting productivity information, a MMS can be used to estimate budgeting requirements to meet LOS targets.	Low	I,H
Moderate	Interfaces with existing systems	Centralized database or shared database structure	The MMS is expected to pull information from various sources as listed in the body of the report. If a client-distributed database structure is available, the data do not all need to be located in a single database, but access to the information is established in a manner that is transparent to the user.	Low	H
Moderate	Data needs	Feature condition assessment	For budgeting purposes it is also important to be able to determine the current and targeted level of service being provided for various features. Some states assess the condition of a representative sample of each feature to determine conditions while other states survey each of the features in the inventory.	Moderate	I,H
Low	Information & reporting needs	Dashboard reporting	Dashboards provide a means of visually monitoring accomplishments toward a target without having to run a report (they are displayed as a user logs onto the system).	Low	I,H
Low	Other needs	Clear responsibilities	An important component of quality assurance is to have clearly defined roles and responsibilities for supporting, operating, and maintaining the MMS.	Low	B,I,H

Pavement Management Options

Since pavement management tools are already in place, only two implementation options are offered for pavement management. The first option improves the existing business processes to better support the Department's pavement preservation program and to make more cost-effective use of its available funding. The first option also includes activities to improve the Department's GIS capabilities to better align with pavement management needs. The enhanced pavement management option includes a recommendation for new pavement management software to conduct the types of analyses needed to fully support a pavement preservation program. The features of the program are similar to those being used in District 6, but utilize software better oriented towards managing a statewide pavement network the size of Idaho's. The state-of-the art software programs used at the state level allow multiple condition indices to be used for recommending treatment options, they can analyze larger quantities of data, and they have more of an open architecture to allow more flexibility in customizing performance models and treatment rules to the unique conditions in each agency.

The two pavement management options are described in more detail in the following sections. Along with the descriptions is a summary of activities that will need to be done in conjunction with the implementation of the software and a table that illustrates which of the defined needs will be addressed with each implementation option.

Option 1: Aligning Pavement Management Business Processes

The Department's current pavement management system addresses most of the Department's planning and reporting requirements. However, in order to expand the analysis capabilities to address the needs of the Districts, there are some processes that have to be addressed. Even if the Department elects not to implement new pavement management software in the near future, it could still benefit from addressing the features included in this option.

The specific areas that should be addressed include the following:

- In addition to reporting pavement needs, a process needs to be developed to consider alternate treatment strategies that include the use of preventive maintenance treatments. As described elsewhere in this report, the ability to analyze alternate treatment strategies allows ITD to compare the consequences of each strategy (in terms of pavement condition) to determine the most cost-effective use of available funding. The current system is limited to analyzing pavement sections once they are defined as deficient. Needs are an important metric to report and will continue to be identified and reported to the legislature and the FHWA. However, additional treatment strategies are needed to better match the cost-effective programs being identified by the Districts.
- The finalization of pavement deterioration rates to predict pavement conditions.
- A centralized database for storing pavement-related information that can be easily accessed by District personnel and others outside pavement management.
- Enhanced GIS capabilities that allow reporting of data in both the ascending and descending directions.
- The establishment of a pavement management committee that represents the broad group of pavement management users to provide input to the system enhancements on an on-going basis.
- Resolution of the inconsistencies way the video log reports distance measurements.

The estimated cost of implementing this option is difficult to predict because it includes activities outside the expertise of the research team. Therefore, the Department should investigate the costs presented in table 13 further before using them for budgeting purposes.

Table 13. Costs associated with implementing **PMS Option 1**.

Activity	Estimated Cost	Comments
GIS improvements and LRS issues	$500,000 - $1,000,000	The research team's scope concentrated on MMS and PMS needs; however both systems would benefit from addressing these improvements as described elsewhere in the report. These include modifying the GIS to be two-directional and eliminating the inconsistencies in the distance measurements with the video log van.
Centralized data warehouse	$1,000,000 - $3,000,000	Developing a central distributed database is a Department-wide activity that is beyond the scope of this project. However, the availability of this feature would be very beneficial to the Districts so they can have real-time access to pavement-related information to assist with project and treatment decisions and in pavement design.
Consulting services and training	$200,000	Some training would be required for collecting, storing, querying, and reporting data.
Total - One-Time Cost	***$1.7 – $4.2M***	

Option 2: Improve Pavement Management Analysis Capabilities

To fully meet the needs of both the Division of Transportation Planning and the Districts, new pavement management software is needed. The types of systems available today can import pavement-related data from various sources for use in the analysis. Multi-year programs can be developed that consider a variety of preventive maintenance, rehabilitation, and reconstruction treatments and help the agency make the best use of available dollars. Multiple strategies can be considered so that needs can be defined as they are now, but recommendations for improvement programs can incorporate lower-cost strategies where they are appropriate. The program should be available to the Districts so they can run their own alternate strategies, but the central office should retain responsibility for running statewide analyses. Additionally, the database structure should be transparent (so data table formats and content are known) so that other applications can be written to the data.

Basic features that will be provided in the new pavement management software are listed below.

- A transparent data structure that defines data table formats and content.
- Statewide access to pavement-related information, including distress type, extent, and severity.
- Integrated performance models that predict future conditions and help illustrate the consequences of various funding strategies.

- Last construction date information needed for GASB-34 reporting.
- Treatment rules that include rehabilitation, reconstruction, and preventive maintenance strategies.
- The flexibility needed to adjust treatment rules as practices change.
- The ability to conduct multi-year analyses to optimize the expenditure of available funding. At a minimum, the system should include tools to perform an incremental benefit cost analysis, or the equivalent.
- Standard and user-customized reporting.
- Import and export capabilities.
- Interfaces with the Department's MMS, GIS, and centralized data sources.

The estimated cost of implementing this option is presented in table 14.

Table 14. Costs associated with implementing **PMS Option 2**.

Activity	**Estimated Cost**
Software	$700,000
Customization and training	$250,000
Total – One Time Cost	***$950,000***
Annual licenses	$50,000

Pavement Management Summary

Table 15 presents a summary of how each of the two options presented in this section address the needs identified in Chapter 3.

Lower Cost Implementation Strategies

Alternate MMS Strategies

Because of significant decreases in available highway funding and the corresponding increases in the cost of construction materials, state transportation agencies are significantly limited in their ability to invest in new programs such as the ones recommended in this report. Recognizing that these limitations exist, the research team considered alternate strategies that might reduce the resource requirements while still providing some of the basic functionality recommended.

Since restoring the basic functionality of the MMS is the highest priority identified during this study, it is very important that ITD invest in MMS software to store and retrieve information about maintenance activities, resources used, and activity location. Ideally, an interface is developed between the new MMS software and the Advantage financial management system, but the interface could be postponed by entering information separately into each system. This approach requires duplicate data entry into two different systems, which is not ideal, but satisfies the need to report maintenance costs, estimate productivity, and perform basic budgeting activities. A summary of the strategies that could be utilized to reduce the cost of the MMS implementation from $2.7M to approximately $900k to $1,250k include those listed below.

- Postpone the development of the interface with the financial management system (Advantage). This will likely result in duplicate data entry that will have to be carefully managed to limit data entry errors.

- Acquire only the most basic modules of the MMS to reduce licensing costs. Consider subscribing to a MMS (rather than licensing the software) if that option is available. Some vendors offer this option at approximately 1/3 the cost of an individual license.

- Rather than use a consultant for the implementation, savings of approximately 25 percent of the consulting fees can be realized by doing most of the implementation work in-house under the direction of the vendor's project manager. Additional savings could be realized by having in-house staff conduct some of the training.

- Postpone the purchase of the handheld GPS units.

To see how the changes identified in this section would reduce cost for acquiring an MMS, see table 15.

Table 15. Options to Reduce Cost of MMS Implementation.

Activity	Estimated Cost	Comments
Basic MMS Cost Estimate	$2,700,000	
- Financial Management System Integration		Eliminate/postpone MMS integration with ITD's financial management system
- Optional System modules		Only acquire most basic modules or subscribe to service rather than purchase MMS
- Consultant Services		Rely on in-house staff to implement system instead of consultants
- GPS		Postpone purchase of handheld GPS units
Reduced Initial Investment	$900,000 - $1,250,000	

The research team does NOT recommend that cost savings be realized through the implementation of less functional software programs. Although these programs may cost less initially, they are frequently limited in their ability to offer improved functionality over time. In recent years there have been two state highway agencies that selected low-cost MMS through their procurement processes. One of the contracts was cancelled after the first phase was completed and the second is behind schedule because the selected software is not meeting the State's needs. These examples illustrate that sometimes short-term cost savings can lead to much higher costs in the long run.

Alternate PMS Strategies

An evaluation of alternate strategies was also conducted to determine whether a lower cost strategy is available to enhance ITD's pavement management analysis capabilities. Since ITD's current pavement management system provides most of the functionality needed for planning purposes, the low-cost strategy focuses on providing Districts with the ability to evaluate alternate treatment strategies using software similar to what is being used in District 6. This strategy provides for each District to obtain a copy of the PavementView Plus pavement management software to evaluate treatment options within their geographic area. District 6 estimates that they have invested approximately $100k in their pavement management capabilities to date. Building on the lessons learned through their implementation, and recognizing that there may need to be some adjustments to the performance models and treatment rules in each District, it is estimated that a similar program could be implemented for approximately $80,000 per District ($400,000 total since District 6 already has a system in place). Training could be performed, in part, by District 6 personnel who are familiar with the operation of the software. A disadvantage to this approach is that it does not provide a means of running a statewide analysis that illustrates the long-term consequences of various scenarios. For the statewide analysis, a more robust system, such as the one included in the original recommendations is required. Selection of this alternate option could also have even larger negative impacts on statewide planning capabilities due to potential losses in the value and availability of data and the current level of understanding with the legislature.

Additionally, the Department should modify its business processes to support the use of more preventive maintenance treatments that defer the need for more expensive rehabilitation treatments. The current system, which focuses on reducing existing deficiencies, is expected to lead to worse long-term conditions than a pavement preservation strategy that includes both preventive maintenance and pavement rehabilitation treatments. The availability of software tools that can evaluate the consequences of these types of programs is also important to the success of a pavement preservation philosophy.

Table 16. Pavement management implementation option summary.

Level of Importance	Feature Category	Identified Need	Description	Degree to Which Currently Addressed	Degree to Which Needs Are Met With Each Option	
					Aligning Business Processes	Improving Pavement Management Analytical Capabilities
High	Data Needs	Consistent Linear Referencing Systems (LRS)	The reference post/off-set method of collecting pavement condition data conflicts with other methods of continuous data collection. This can lead to discrepancies in location referencing that vary depending on the direction of travel.	Low	√	√
High	Information & Reporting Needs	Real-time access to the pavement management database	Timely access to pavement-related information allows pavement condition information to be used when it is needed, rather than when reports become available.	Low	√	√
High	Information & Reporting Needs	Remote access to pavement management information	It is estimated that both District and HQ personnel will access the pavement management database at some level. Some will be power users who perform analyses, but others will primarily perform queries or run reports.	Low	√	√
High	Analytical Functionality	Optimization analysis of alternate strategies	The current pavement management system supports many of the decisions at the strategic and network level, especially reports needed for planning purposes. The current software is somewhat constrained in the type of analyses that can be conducted, which limits its usefulness at other levels within the Department.	Low		√
High	Analytical Functionality	Broader definition of needs	The current strategy for defining needs uses functional class to describe intervention levels. Since traffic levels vary significantly within a functional classification, the current definitions do not always adequately define realistic needs.	Moderate	√	√
High	Analytical Functionality	Pavement performance modeling	Planning has developed some pavement performance models for its purposes, but the models have not been used to support engineering analyses. Ideally, a pavement performance modeling tool is built into the pavement management system.	Moderate	√	√
High	Interfaces With Existing Systems	GASB-34 reporting requirements	A process is needed so pavement restoration and reconstruction information are available for GASB-34 reporting prior to the close of each fiscal year.	Low		√
High	Interfaces With Existing Systems	Consistencies in data collection processes for GIS	The pavement condition survey data are collected using a mile posts and offsets. This approach causes conflicts with the continuous measures used in GIS that cause inefficiencies and may lead to data errors.	Low	√	√
High	Interfaces With Existing Systems	Work history records	As improvements are made to the pavement network, it is important that any activity that resets the condition indexes, resets the last resurfacing date, or changes the surface type are reported to pavement management on a timely basis.	Moderate		√

Table 16. Pavement management implementation option summary (continued).

Level of Importance	Feature Category	Identified Need	Description	Degree to Which Currently Addressed	Degree to Which Needs Are Met With Each Option	
					Aligning Business Processes	Improving Pavement Management Analytical Capabilities
High	Interfaces With Existing Systems	Preservation of existing interfaces	The current pavement management software interfaces with a number of different sources to define transportation and environmental features, segment location, and traffic data. These links need to be preserved to provide basic inventory information critical to pavement management.	High		√
High	Other Needs	User-friendly	The user interfaces should be easy to use, information should be displayed graphically, and an easy query function should be available.	Low		√
High	Other Needs	Training	Several different types of training are needed to teach pavement management concepts and the use of pavement management information to support decisions at each of the three levels (strategic, network, and project levels).	Low		√
High	Other Needs	Long-term maintenance plan	Processes should be developed to help ensure the long-term viability of the pavement management system if new software is implemented.	Low		√
High	Other Needs	System flexibility	The Department operates in an environment that constantly changes. Therefore, the system should be flexible enough to adapt to changes in policies, practices, or procedures.	Low		√
High	Analytical Functionality	Analysis support for decisions at the strategic, network, and project level	A pavement management system should support decisions at the strategic, network, and project levels.	Moderate		√
High	Information & reporting needs	International Roughness Index (IRI) rather than Roughness Index for reporting to FHWA	The FHWA's Highway Performance Monitoring System (HPMS) requires that roughness data be reported in terms of the IRI. ITD currently reports it in terms of a Roughness Index and has been able to get exceptions from the FHWA to report it this way. However, the FHWA is updating its reporting requirements and it is possible that an exception may not be granted in the future.	Low		√
Moderate	Data Needs	Detailed distress information	Information on the type, severity, and extent of cracking information is collected as part of the annual pavement condition surveys but the information is not easily accessible to District personnel. Rutting information has not been incorporated into the deficiency calculations due to a lack of confidence in the data.	Low	√	√
Moderate	Data Needs	Pavement-related information useful for design	Real time access to information on pavement construction history, geometrics (roadway width and shoulder information), deflection testing.	Low	√	√
Moderate	Data Needs	Two-directional GIS displays	GIS data is stored and reported using a single line to represent both directions of travel. To display work activities by direction or to link data to particular lanes requires modification to the existing GIS.	Low	√	√

Table 16. Pavement management implementation option summary (continued).

Level of Importance	Feature Category	Identified Need	Description	Degree to Which Currently Addressed	Degree to Which Needs Are Met With Each Option	
					Aligning Business Processes	Improving Pavement Management Analytical Capabilities
Moderate	Data Needs	Transparent access to data	Data table structures and access to information should be provided for generating queries, linking the PMS to new systems, or writing applications. Complete metadata that describes data context, content, structure, and management would also be useful.	Low		√
Moderate	Data Needs	Import/export capabilities	It will be important to be able to import and export data from sources both inside and outside the Department.	Low		√
Moderate	Information & Reporting Needs	Centralized storage of pavement-related information	Pavement-related information is currently stored in disparate locations, further hindering the access to this information. For example, nondestructive deflection testing and skid test results are typically stored in project files rather than in the pavement management database.	Low	√	√
Moderate	Information & Reporting Needs	GIS Displays	There are a number of useful GIS displays that could be developed. For instance, users can display pavement sections that have not been sealed for 7 or more years.	Moderate	√	√
Moderate	Interfaces With Existing Systems	MMS interface	Coordinated capital and maintenance improvement plans require that an interface exists between pavement management and MMS to assist in the project selection process.	Low		√
Moderate	Interfaces With Existing Systems	Central location for all pavement-related information	Pavement-related data are stored in various locations depending, primarily on the data source. A centralized, client-server architecture would improve access to information collected by different sources.	Low	√	√
Low	Information & Reporting Needs	Consequences due to inflation	The budget is largely driven by inflation, which can not be controlled by the Department. It would be helpful to some users to be able to evaluate the consequences of inflation on future network conditions.	Low		√

CHAPTER 6.0 – RECOMMENDATIONS

Maintenance management and pavement management systems are important tools that can drastically enhance the effectiveness of a transportation agency's decisions. A comprehensive MMS provides an integrated set of business processes and analysis tools that support performance-based budgeting, resource management, and scheduling. MMS have a strong customer focus so improvements in maintenance efficiency associated with the implementation of a MMS help agencies better meet customer expectations and more effectively utilize tax dollars. Agencies utilizing MMS report a number of improvements in their decision processes and cite the following types of benefits (AASHTO 2005):

- Improved outcome-based accountability.
- Stronger links between customer expectations and program activities.
- Increased service levels.
- Reduced operating and maintenance costs.
- Better accessibility to information for performance measures.
- Improved practices and efficiencies.

Pavement management systems provide a defensible approach to managing a pavement network resulting in the most cost-effective use of available resources. By comparing the results of different investment levels and/or preservation strategies, an agency can quickly determine the potential long-term consequences and risks associated with its pavement maintenance and capital improvement choices. Agencies are better able to defend their funding requests and to communicate the expected network performance associated with various investment levels. A number of agencies have been able to use the results of their pavement management analysis to secure increased funding for pavement preservation activities.

Even if a pavement management system is not used to secure additional funding, agencies can realize a number of benefits associated with their use. These analysis tools enable an agency to quickly evaluate large amounts of information so that cost-effective pavement improvement strategies can be identified. The AASHTO *Pavement Management Guide* lists the following benefits associated with the use of pavement management software (2001):

- More effective use of available resources.
- Better information to justify resource expenditures.
- More accurate and accessible roadway information.
- Better ability to track and model treatment performance.
- Improved needs analysis capabilities.
- Better ability to show the impact of funding decisions.
- Increased access to information needed to respond to various queries.
- Better coordination with other highway organizations.
- Improved credibility.
- Improved communication between the organization, the public, and other highway users.

The implementation of maintenance management and pavement management software often requires changes to the way a transportation agency does business. The agency's investment decisions should support the more cost-effective use of available resources and individuals at all levels of the organization should support this overall philosophy. Investments in technology and organizational improvements are often needed to support the demand for improved accessibility to information from remote users. These systems require quality data, so processes should be developed to ensure that the information remains current, that it is provided on a timely basis, and that it provides the type of information needed to make decisions.

The results of this research study illustrate that there are numerous approaches for ITD to consider as it strives to improve its maintenance management and pavement management capabilities. In a perfect world, unlimited resources would be available to address all of the needs identified in Chapters 2 and 3 and new maintenance management and pavement management software could be implemented immediately. Realistically the agency faces resource constraints that may require a phased implementation or force the agency to implement only the MMS or PMS software program at this time.

Maintenance Management System Recommendations

Recognizing that a phased implementation may be required, the research team developed three different options for implementing a new MMS, with each option adding complexity and resource requirements. At this point in time, the research team recommends that the agency move forward immediately with Option 1, to implement basic cost-accounting features using new maintenance management software provided by a commercial vendor. This implementation package requires an interface with the Department's new financial management system (Advantage). An interface should be developed so that the needs of both maintenance and human resources are addressed. Once this system is in place, or as the system is being implemented, the Department should begin work towards developing the performance-based budgeting tools outlined in Option 2. The development of a Maintenance Quality Assurance (MQA) program could be done concurrently with the work activities required in Option 1, which would reduce the amount of time before performance-based budgeting could be used. The LOS definitions previously developed as part of the PRIMO study provide an excellent foundation for the MQA program. Based on studies within other states, these first two options could be completed within a 3- to 5-year window, assuming adequate resources are provided.

This recommendation requires the interfaces illustrated in the figure 9 to be developed, at a minimum.

Pavement Management Recommendations

Although the research team strongly recommends the use of pavement management systems to support the identification of cost-effective pavement improvement programs, there is a much stronger need to immediately acquire basic maintenance management capabilities than to replace the pavement management software. Therefore, the research team recommends two implementation strategies for pavement management. Option 1 recognizes that funding may be limited and resources may only be available to install maintenance management software. If that is the case, Option 1 provides recommendations for other changes that are needed to improve the functionality of the pavement management system and to better address the needs of District personnel. Included in Option 1 is the development of alternate pavement treatment strategies that will help District personnel better identify and prioritize cost-effective pavement repairs. The current approach, which is based primarily on needs, should be preserved for planning and

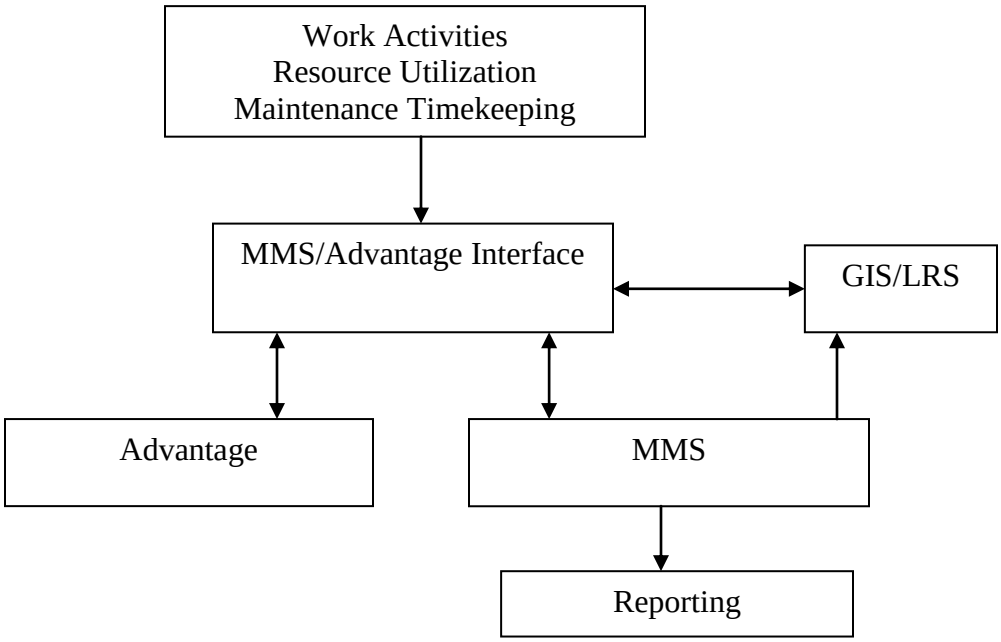

Figure 9. MMS process map.

reporting purposes, but new business processes that include the use of preventive maintenance treatments are required to keep the existing pavement network in good condition under the expected funding constraints. It also includes the development of a distributed database to improve the access to pavement-related information by the Districts. The availability of this information would be beneficial in project and treatment selection and in developing pavement designs.

The research team recommends that new pavement management software be implemented, as identified in Option 2. The functionality of the existing pavement management tools are limited in their ability to address the Districts' needs. Without a Departmental-wide program in place, individual Districts may continue using resources to develop their own analysis tools and competing approaches to pavement management may emerge. During periods with constrained funding availability, such as that being faced by ITD, it is more important than ever that the agency develop a cohesive strategy towards pavement management.

It should be noted that the implementation of Option 2 does not eliminate the need for the Department to address the concerns identified in Option 1. These changes are still needed for an adequate number of treatment options be considered in the analysis; however enhanced pavement management capabilities (including the ability to analyze alternate treatment strategies) can be provided without completing the activities listed in Option 1 and only completing the activities listed in Option 2. However, under this scenario, the pavement management system becomes the repository for all pavement-related information, as shown in figure 10. Approximately two years should be scheduled for implementation of the new pavement management software, which can be done concurrently with enhancements in data storage and GIS.

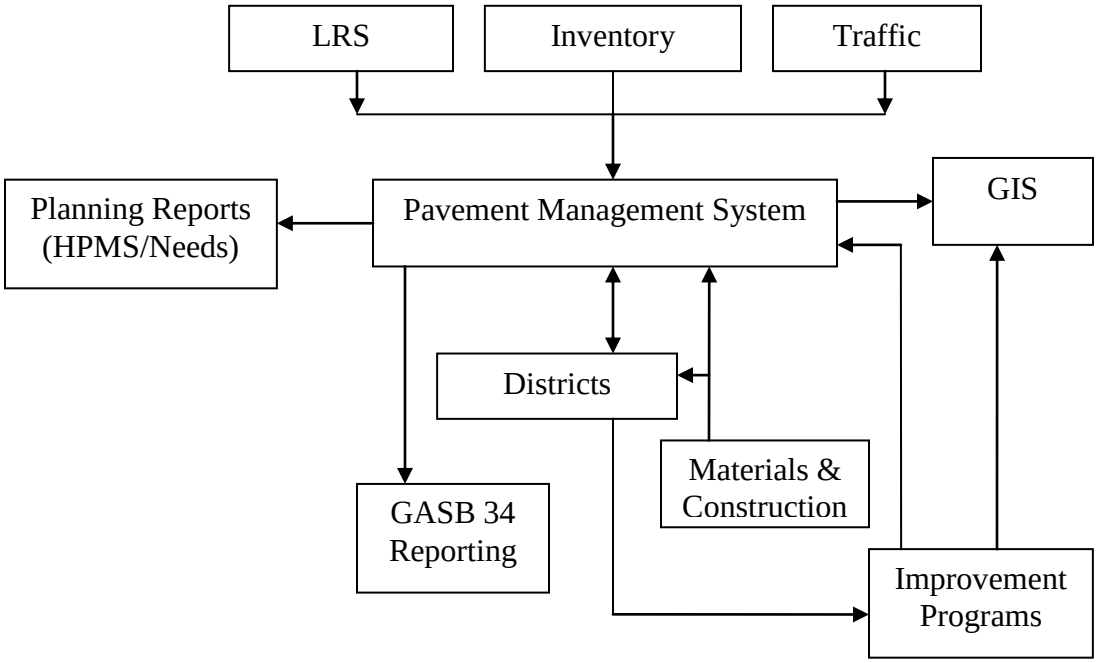

Figure 10. Pavement management process map.

Other Recommendations

Both of the recommendations presented to ITD have a training component to familiarize agency personnel with the changes that are being made and to help ensure that the new business processes are followed. The training can be provided from several sources. One of the most obvious sources of training is the vendor selected for the implementation of the MMS and PMS software. This training will primarily include hands-on training in the operation of the software.

In addition, training is available from outside sources. If a consultant is hired to work with ITD to develop MQA ratings to report LOS, a part of the contract should include training of ITD personnel once the rating methodology is developed. In addition, the Department should consider hosting training provided by the National Highway Institute, the FHWA's training arm. In particular, ITD should consider NHI Course 131107, *Principles and Practices for Enhanced Maintenance Management Systems* and NHI Course 131116, *Pavement Management: Characteristics of an Effective Program*. The second of these courses is offered free of charge to SHAs.

It is important that customization and implementation of the new MMS software should involve District and Division of Highways representatives. Their participation in documenting the existing work processes, customizing user interfaces, and testing the new software will go a long way towards ensuring the success of the system. The individuals involved can also serve as change agents to help bring other field personnel on board. They should also be involved in the changes to the new business processes associated with pavement management to help ensure that the new treatment rules represent the types of recommendations being applied in the field. The development of a committee to guide the system development has proven beneficial in other states.

The ITD should work with Corporate IT staff in the Division of Administrative Services to identify a project manager who will provide guidance during the selection process and help ensure adequate IT capacity is available and plans are in place for on-going maintenance of the software. Due to the number of interfaces that will have to be developed, the assistance of IT is especially important.

Return on Investment

The recommendations included in this report represent a significant investment of ITD resources. However, in exchange for the investment, the agency can expect to realize numerous benefits, such as those listed below from the American Association of State Highway and Transportation Officials (AASHTO) in its *Pavement Management Guide* (2001).

- More efficient use of available resources.
- The ability to justify and secure more funding for pavement maintenance and rehabilitation.
- More accurate and accessible information on the roadway system.
- The ability to show the impact of funding decisions.
- The selection of more effective maintenance and rehabilitation strategies.
- Improved communication between stakeholders both within and external to the organization.
- The ability to better answer questions from management, elected officials, and the public.
- Improved creditability when dealing with management, elected officials, and the public.

To date, it has been difficult to quantify these benefits in monetary terms that allow an agency to determine its return on the system investment. No quantitative information on the benefits associated with the implementation and use of a MMS is available in the literature, but the *Guidelines for Maintenance Management Systems* lists the following subjective benefits (AASHTO 2005):

- Maintenance quality rating systems help define asset conditions in customer-oriented terms.
- With limited budgets, managers can decide between competing needs.
- A MMS can help link customer expectations with desired outcomes and results.
- A MMS can link desired outcomes to resource and budget needs.
- Managers can assess the consequences of shifting funds between competing program objectives.

Several research studies have documented the benefits associated with the use of pavement management systems and the more cost-effective treatment strategies recommended. One study, which is based on an analysis of the costs and benefits realized by the Arizona DOT, shows a $30 savings in pavement expenditures for every dollar spent on the development, implementation, and operation of a pavement management system (Hudson et al. 2000). The cost savings were realized by the agency's selection of more preventive treatment strategies, as recommended by the pavement management system, rather than waiting until pavements were

badly deteriorated. The availability of models to forecast deterioration and treatment performance was also noted as a factor in the cost savings.

Another way of looking at the return on investment is through a benefit cost analysis that compares the benefits associated with the use of pavement management to the costs associated with the implementation and operation of the system. A benefit cost analysis conducted on data from the Ministry of Transportation in Alberta, Canada shows a ratio of 100 to 1 due to the improvements in serviceability associated with the use of pavement management (Hudson and Haas 1994). A similar analysis for the Arizona DOT system showed a benefit to cost ratio of 14 to 1 within the first year of the pavement management implementation, even when only agency costs and benefits are considered. If user benefits and costs had been considered, the ratio would have been considerably higher (Cowe Falls et al. 1994).

These studies indicate that an investment of $5M in management systems could lead to $150M in savings in rehabilitation needs through the use of more cost-effective pavement preservation strategies that extend pavement life at a relatively low cost. Further, these studies demonstrate that even if only a portion of the benefits can be attributed to the use of management systems, the benefits realized far outweigh the associated implementation and operational costs. Assuming similar ratios could be realized by ITD, the recommended investment level of $2.7M for MMS and $0.95M for PMS could lead to almost $110M in savings through the use of a more cost-effective program (a benefit to cost ratio of approximately 30 to 1). Using the more conservative benefit to cost ratio determined for the Arizona DOT (a 14 to 1 ratio) will still result in savings estimated to be greater than $50M.

Closing

It is important to emphasize that ITD is fortunate to have personnel who are committed to the enhancement and improvement of its practices and policies. The individuals who participated in this research study were generous with their time and forthright in describing their current and desired capabilities. There is strong support for the implementation of the recommendations from this research study among Department personnel and strong backing for the statewide use of cost-effective pavement preservation strategies. The enthusiasm and support for these programs are important ingredients to the overall success of the maintenance and pavement management enhancements selected by the agency.

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APPENDIX A

THE USE OF HIGHWAY MAINTENANCE MANAGEMENT SYSTEMS IN STATE HIGHWAY AGENCIES

Introduction

The American Association of State Highway and Transportation Officials (AASHTO) published its *Guidelines for Maintenance Management Systems* in 2005. To assist with technology transfer efforts associated with the principles and practices contained in the *Guidelines*, the Federal Highway Administration (FHWA) sponsored the development of a new National Highway Institute (NHI) training course, *Principles and Practices for Enhanced Maintenance Management Systems,* which was completed in December 2005.

To support the development of the training course, a questionnaire was developed to capture the state-of-the-practice in maintenance management systems (MMS). The survey was prepared in cooperation with members of the FHWA Technical Panel overseeing the course development and distributed to state highway agencies through the AASHTO Highway Subcommittee on Maintenance (SCOM) in November 2005. A total of 29 state highway agencies responded to the survey, ranging in network size from less than 2,500 miles to more than 170,000 miles. Of the 29 agencies that responded to the survey, only 2 indicated that they did not have a MMS in place.

Questionnaire Results

The ages of the existing MMS vary greatly among state highway agencies. Asked to provide dates when the system was initially implemented and last updated, agencies indicated that less than half of the existing systems were implemented in the last 5 years. The original implementation dates reported during the survey are shown in figure 1.

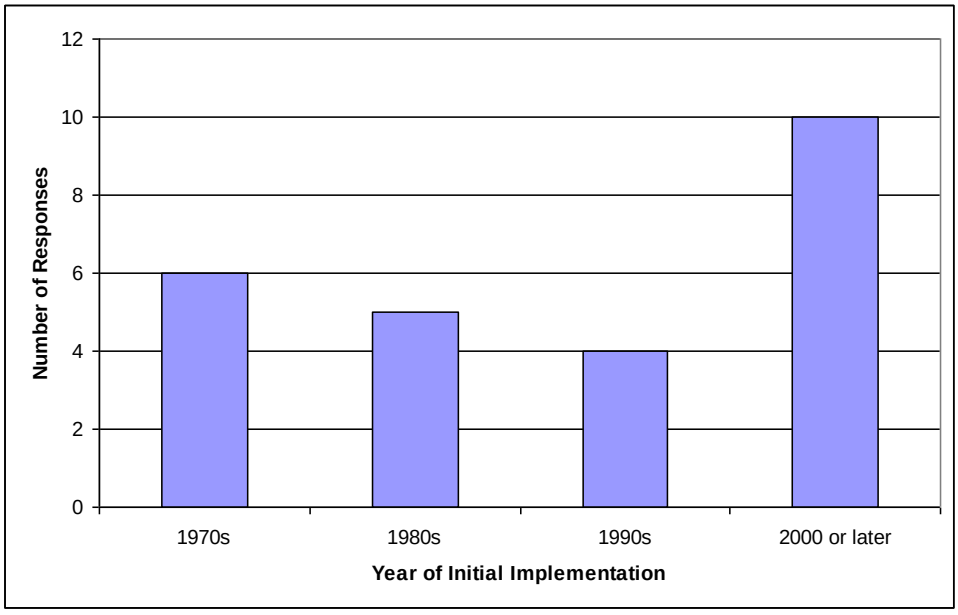

Figure 1. Dates of initial MMS implementation.

Most of the existing MMS have been updated in recent years. The responses to the date of the last system update are shown in figure 2.

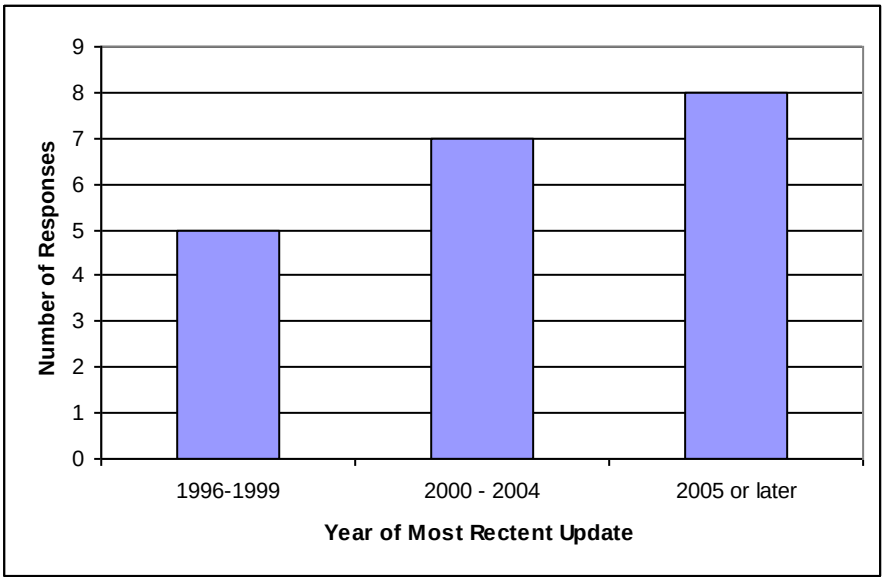

Figure 2. Year of most recent MMS update.

The participants were asked to describe the type of system currently in place. The following options were provided:

- A customized software program developed (or being developed) by a consultant for the agency.
- A proprietary system developed (or being developed) and licensed through a consultant or vendor.
- A system developed (or being developed) in-house.
- A consultant-based system that has been enhanced by the agency.
- A system developed (or being developed) jointly with other public agencies.
- Another type of system.

As shown in figure 3, the responses indicate that consultant-based systems are most commonly used, although seven (7) agencies indicate that they are developing a system in-house. In addition, two respondents are working together, in conjunction with a third state, to develop a system that will be shared by each agency. No agencies reported that a different type of system is in place.

During the last several years tremendous changes have occurred in the types of features provided by computerized MMS. This is reflected in the status of the MMS implementation reported by state highway agencies that participated in the survey. For example, in response to a question regarding the status of their system implementation, 14 agencies indicated that a fully implemented system of some type was in place. However, 20 agencies indicated that they are implementing a new MMS, planning enhancements to their MMS, or implementing enhancements to their MMS. Eight of the agencies planning enhancements indicated that they have completed the implementation of a new, enhanced MMS that will be further enhanced in the future. Although initially two agencies indicated that they did not have a MMS, four agencies selected that option in response to this question. The results are presented in figure 4.

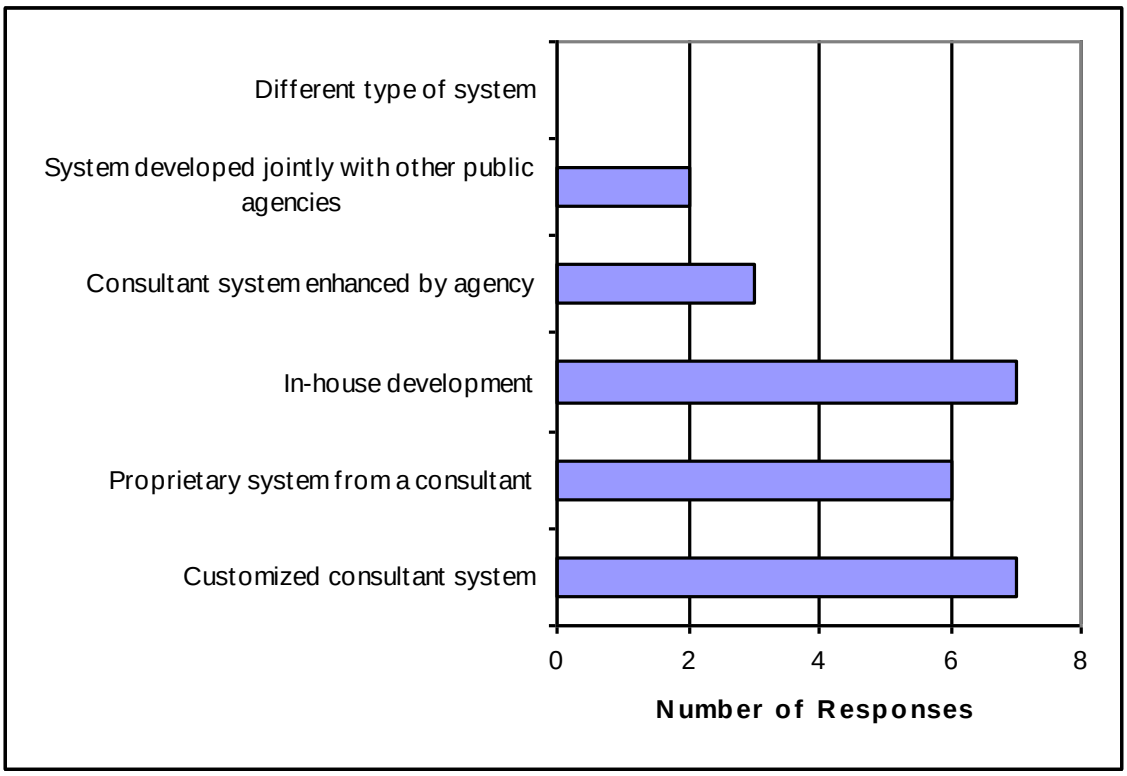

Figure 3. Type of MMS in place.

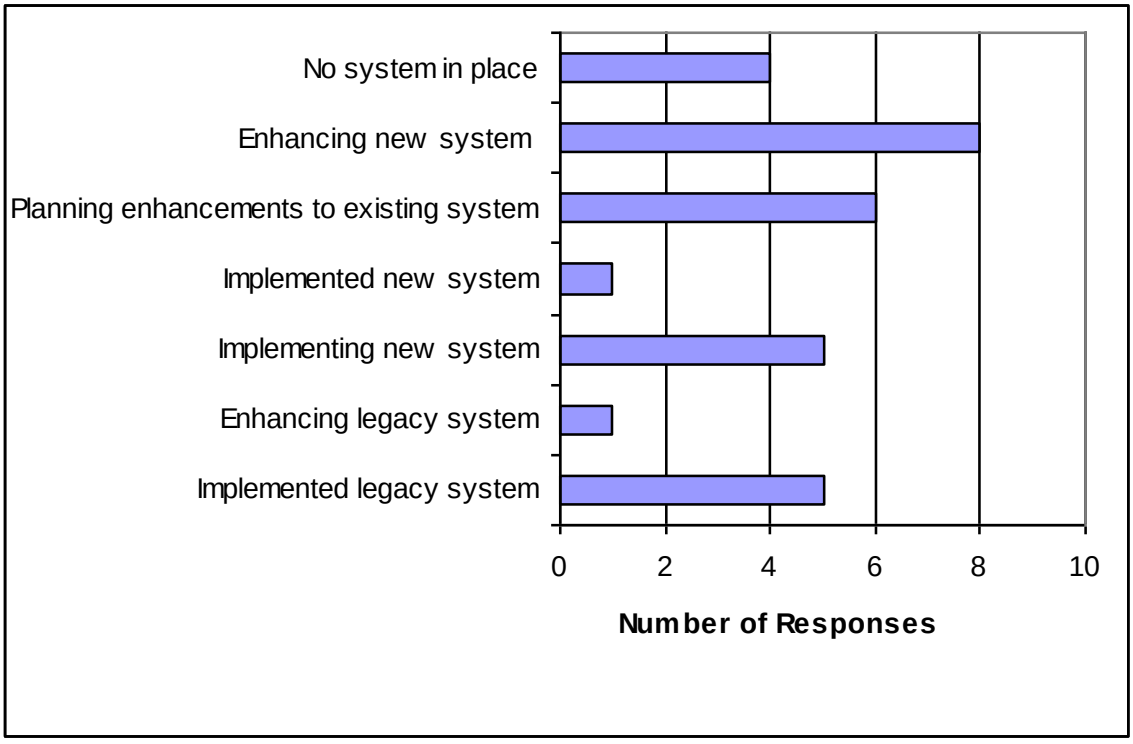

Figure 4. MMS implementation status.

Maintenance Management System Characteristics

The *Guidelines for Maintenance Management Systems* describes today's MMS as an important business tool for "improving maintenance efficiency and increasing service levels" (AASHTO 2005). Today's systems differ from the legacy systems that were initially implemented during the late 1960s or early 1970s and have traditionally been used to capture and report basic information such as inventory quantities, planning, scheduling, and production or output measures. The new systems build on the capabilities provided by the legacy systems with more of a focus on performance-based planning and budgeting, customer-service delivery, and the analysis of various investment strategies based on economic analysis and reliable data. Ideally, recommendations from today's enhanced MMS incorporate information from other management systems so that investment decisions can be optimized.

To determine the prevalence of some of these characteristics in state highway agencies, the questionnaire asked respondents to indicate the types of terms that could be used to describe their MMS. Although the characteristics weren't separated in the survey, for reporting purposes the characteristics have been separated into characteristics associated with a legacy system and those associated with a new, enhanced MMS. Based on the survey results, a large number of agencies have adapted characteristics associated with the newer, outcome-based systems that use performance measures for planning and budgeting activities. The characteristics and the number of responses provided for each characteristic are listed below.

Characteristics Associated With Legacy Systems

- Legacy system (10)
- Output based (14)
- Outdated (11)
- Stand alone system (6)

Characteristics Associated With a New, Enhanced MMS

- Customer-oriented (6)
- Outcome based (12)
- Linked to performance measures (13)
- Integrated into the agency's decision process (12)
- Client server system (7)
- Web based (9)
- Linked or interfaced with other systems (20)

The characteristics and capabilities of MMS were further explored through the use of a table listing features of a MMS that enabled participants to identify whether those features are available in their MMS, desired in their MMS, or scheduled to be added in the near future. Table 1 summarizes the responses to this question. As one would expect, the more traditional features, such as Work Tracking and Annual Work Program, are currently available in most systems.

Table 1. Status of MMS Capabilities and Features.

Feature	Available in the Current MMS	Desired in the Current MMS	Adding to the MMS
Asset Inventory	16	6	7
Condition Assessment	8	7	11
Levels of Service (LOS)	9	6	6
Performance Targets	9	8	7
Performance-Based Budgeting Analysis	10	9	8
Annual Work Program	19	5	5
Annual Budget	14	5	8
Resource Needs Analysis	11	9	6
Work Tracking	25	1	3
Work Needs Identification	14	6	7
Work Scheduling	15	6	5
Staff Allocations	14	6	4
Work Order Development	12	5	6
Hours Worked for Payroll	20	2	4
Customer Service Program	7	6	6
Management Analysis	16	6	6
What-If Analysis	7	10	7
Trade-Off Analysis	4	10	6
Single Point Data Entry	15	5	4
Electronic Data Capture	11	5	10
Global Positioning System (GPS) for Location Referencing	6	8	13
Geographic Information System (GIS) Interface	7	8	11
Interface with Other Decision Processes	6	9	11

However, some of the newer features, such as electronic data capture, what-if and trade-off analysis, global positioning system (GPS), geographic information system (GIS) interface, and the interface with other decision processes are desired or going to be added by many agencies.

In addition to questions about general capabilities, the survey asked participants to report on several specific features associated with their MMS. For instance, performance targets, or targeted levels of service, are used in a MMS to establish the level of service desired by the agency for each asset. Performance targets can be established using a number of different approaches, including customer surveys or focus groups, historical trends, or input from experienced maintenance personnel. Participants in the survey were asked to report the approach used to set their agency's performance targets. Figure 5 presents the results that were received. Several agencies reported that they use several factors together in setting performance targets, such as the use of historical data together with the input of experienced maintenance personnel. Other data sources that were identified include the International Roughness Index (IRI), funding levels, the legislature or transportation commission, management, existing management systems (such as pavement management), or daily work accomplishments.

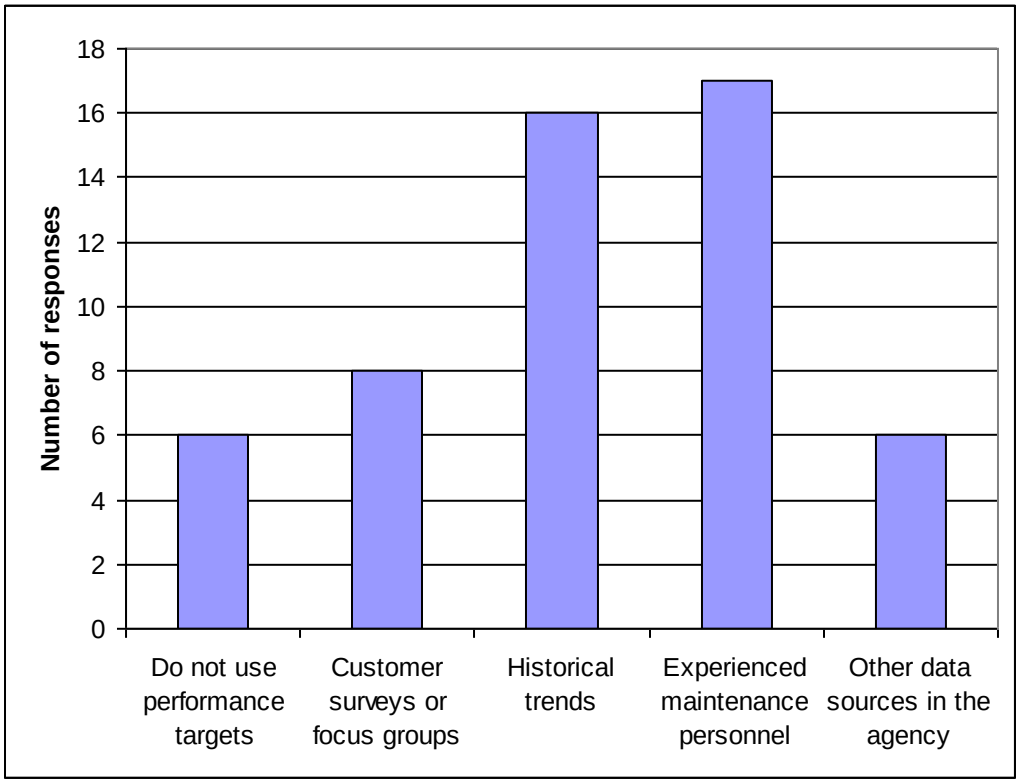

Figure 5. Factors used to develop performance targets.

The survey also asked participants to summarize the degree to which the MMS interfaces with other systems, such as pavement management systems or financial management systems. Participants were asked to identify which systems were not available within their agency, which systems interface with the MMS, which systems are available but not interfaced, and whether an interface with the MMS is under development. A summary of the responses provided are included in table 2. As shown in the table, most existing MMS interface with financial management systems, equipment management systems, the roadway inventory, and bridge management systems. Some interfaces are under development with the largest number of agencies working on an interface with the geographic information system (GIS).

Data Collection Features

Maintenance management systems require reliable data to support the different types of analyses that are conducted. For the most part, these data are collected by in-house forces although some agencies collect data by contract forces (especially data on pavements and structures). The method of data collection varies depending on the type of data collected, although paper and pen remains the most common approach to recording inventory and condition data. The largest use of vans for data collection is associated with the conduct of pavement inventories and condition surveys. These results are summarized in tables 3 and 4, for inventory and condition data, respectively.

The survey also asked participants to report on the frequency of data collection activities and whether sampling was used as part of the agency's maintenance quality assurance (MQA), feature/asset inventory, or LOS surveys. The responses provided in table 5 indicate that sampling approaches are used to some degree with 0.1-mile samples being most common.

Table 2. Interfaces with the MMS.

Type of System	System Not Available in Agency	System Interfaces with The MMS	Interface Under Development	System is Available But Not Interfaced
Pavement management	1	5	3	19
Bridge management	0	11	2	15
Financial management	0	18	1	8
Equipment management	0	18	1	9
Safety management	9	2	2	12
Construction management	1	2	1	23
Roadway inventory	4	16	3	4
Geographic Information System	1	5	5	17
Sign management	8	7	2	9
Pavement marking management	13	7	0	6
Signal management	11	5	1	8
Other systems	0	5	2	1

Table 3. Data collection approaches for inventory data.

Asset Type	Approach		Inventory Data Collection Method				
	In-house	Contract	Paper & Pen	Handheld Device	Video in Van	Digital Images in Van	Other
Drainage features (culverts, curb & gutter)	20	4	16	9	4	1	0
Roadside features (fences, brush, mowing)	20	2	16	6	2	2	0
Pavement features	22	9	11	5	13	12	2
Structures (bridges, overhead sign structures)	24	7	18	9	5	3	2
Traffic items (signs, signals)	22	2	16	8	3	1	1
Guardrail and attenuators	21	4	16	6	5	3	0
Other facilities (tunnels, rest areas)	20	2	16	4	2	1	1

Table 4. Data collection approaches for condition data.

Asset Type	Approach		Inventory Data Collection Method				
	In-house	Contract	Paper & Pen	Handheld Device	Video in Van	Digital Images in Van	Other
Drainage features (culverts, curb & gutter)	22	3	20	6	1	1	0
Roadside features (fences, brush, mowing)	21	3	20	5	1	1	0
Pavement features	23	7	14	4	9	6	4
Structures (bridges, overhead sign structures)	23	5	18	8	0	0	2
Traffic items (signs, signals)	23	1	17	5	0	0	1
Guardrail and attenuators	20	4	17	5	0	1	0
Other facilities (tunnels, rest areas)	21	2	15	5	0	0	2

Table 5. Use of sampling during surveys.

Asset Type	100% Coverage	Sampling Approach				
		No samples	0.10-mile samples	0.25-mile samples	0.5-mile samples	Other
Drainage features (culverts, curb & gutter)	6	3	7	0	2	5
Roadside features (fences, brush, mowing)	3	4	7	0	2	6
Pavement features	11	4	8	0	1	4
Structures (bridges, overhead sign structures)	14	6	2	0	0	3
Traffic items (signs, signals)	7	4	6	0	2	4
Guardrail and attenuators	6	5	6	0	2	6
Other facilities (tunnels, rest areas)	11	5	2	0	1	4

Survey frequencies, which are provided in table 6, vary slightly depending on the type of asset being considered. Annual surveys are most common for every asset except structures, which are more typically inspected every other year. Some agencies also report that different frequencies are used depending on the functional classification of the road.

Table 6. Survey frequency.

Asset Type	Annually	Every Other Year	Every Third Year	One Half of Network Each Year	One Third of Network Each Year	Other	Don't Have a MQA or LOS Program
Drainage features (culverts, curb & gutter)	13	3	0	0	0	6	2
Roadside features (fences, brush, mowing)	14	1	0	0	0	4	3
Pavement features	16	5	1	0	0	2	1
Structures (bridges, overhead sign structures)	5	10	2	1	0	2	1
Traffic items (signs, signals)	11	1	1	1	0	5	2
Guardrail and attenuators	13	2	1	0	0	5	2
Other facilities (tunnels, rest areas)	9	2	1	0	0	6	2

The final question asked participants to report on the types of enhancements that are planned for their MMS. As shown in figure 6, a large number of agencies are planning to update their asset inventories, improve the interface with other systems, improve their LOS approach, or develop enhanced performance targets. Other enhancements that were listed by respondents included the development of web-based modules, tracking and material re-ordering modules, and the addition of incident reporting/first report of injury work orders.

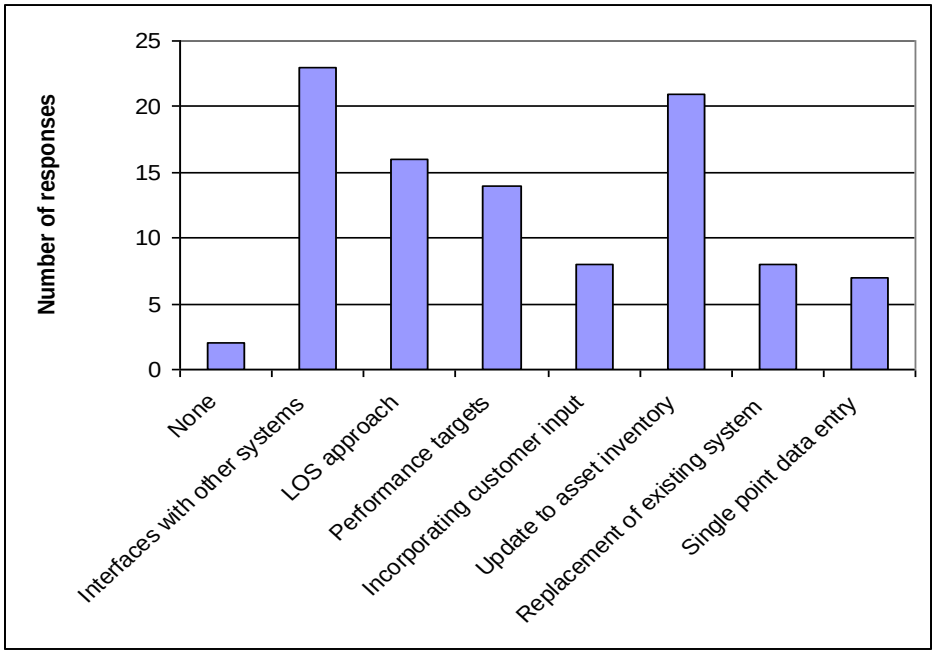

Figure 6. Planned enhancements to existing MMS.

Summary

Maintenance management systems in state highway agencies are undergoing significant changes. While many agencies are using MMS that were initially implemented more than 15 years ago, a significant number of agencies have updated their system capabilities or have plans in place to update or replace their older systems. Most of these systems have been developed and implemented by consultants, although there are a number of agencies that have developed enhanced systems using in-house forces. There is also one system that is being developed through a partnership between three state highway agencies.

The types of enhancements that are under development vary dramatically. While most state highway agencies report that their MMS provides work tracking, payroll hours, and the annual work program, there are a number of desirable capabilities that are not currently available in the legacy systems. For instance, several agencies expressed interest in adding what-if and trade-off analysis capabilities, resource needs analysis, performance-based budgeting analysis, and stronger interfaces with other decision processes and existing geographic information systems. The capabilities being added by most agencies include the interfaces with existing systems, the use of global position systems (GPS) for location referencing, electronic data capture, and improved condition assessment techniques.

Today's MMS require reliable inventory and condition data. Most of this information is collected using in-house forces, although contract forces are used for pavement and structure data. Most data collection is conducted using manual processes, although automated vans are used by many state highway agencies for pavement features. Annual surveys are conducted most often with the exception of structures, which are more typically inspected every other year.

References

American Association of State Highway and Transportation Officials (AASHTO). 2005. *Guidelines for Maintenance Management Systems.* American Association of State Highway and Transportation Officials, Washington, DC.

APPENDIX B – E

RFP's from Various State DOT's.

These are available upon request from:

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