PAVEMENT MANAGEMENT ROADMAP

U.S. Department of Transportation
Federal Highway Administration

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16. Abstract

The Federal Highway Administration (FHWA) sponsored the development of a Pavement Management Roadmap to help identify the steps needed to address current gaps in pavement management and to establish research and development initiatives and priorities. This document presents an overview of the 10-year Pavement Management Roadmap, which can be used to guide new research, development, and technology transfer opportunities that will lead to improved approaches to pavement management.

The roadmap was intented from the beginning to be a collaborative process that would involve representatives from each of the various stakeholder groups that either use pavement management data, support the use of pavement management concepts, or provide technical assistance or training to current or future pavement management practitioners. The contents of this roadmap were derived from a series of stakeholder workshops in which representatives from state and local agencies, academia, private industry (including data collection and software vendors), FHWA, and others met to discuss and prioritize the needs of pavement management professionals. The resulting needs were organized and grouped into one of the following four themes that emerged from the process: Theme 1: Use of Existing Tools and Technology; Theme 2: Institutional and Organizational Issues; Theme 3: The Broad Role of Pavement Management; and Theme 4: New Tools, Methodologies, and Technology.

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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	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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1.0 Introduction

Over the last few decades, transportation agencies have seen tremendous changes in the way business is conducted. For example, since the construction of the interstate highway system, there has been an increased emphasis on performance monitoring and the use of pavement management data to assist with planning and programming for maintenance activities and capital improvements. Additionally, the methods used to assess pavement condition have evolved in conjunction with other technological advancements so that automated procedures are more commonly being utilized than in the past. Moreover, advancements in computer capabilities and their availability have resulted in a plethora of new tools for designing, analyzing, and managing pavements. Most recently, this has led to the development of new mechanistic-empirical pavement design procedures with significantly larger and more diverse data requirements than have been previously used.

In addition to technological changes, transportation agencies have seen adjustments in the way decisions are being made. Within the past 10 years, there has been an increasing emphasis on asset management principles for resource allocation and utilization decisions that are based on system performance objectives. Under an asset management framework, investment decisions consider the trade-offs associated with different strategies and agencies strive to align tactical improvement programs with their strategic priorities. With asset management there is an increased focus on customer expectations and transparency in the decision process. The availability of quality data has a tremendous impact on an agency's ability to compare different investment options and to make sound business decisions that consider both engineering and economic factors.

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Unfortunately, decreases in the purchasing power of available funding, coupled with reduced funding levels, have led to deteriorating network conditions within most transportation agencies at the same time that demand for these facilities is increasing. As a result, many transportation agencies are shifting their priorities from a focus on system expansion to an increasing focus on system preservation. In fact, a number of agencies have recognized the cost-effectiveness associated with the use of preventive maintenance treatments to slow the rate of deterioration and to postpone the need for the most costly rehabilitation strategies. However, the shift towards pavement preservation has not been entirely free from problems. For example, organizations that had previously separated the maintenance and capital improvement decision processes have had to overcome these institutional barriers in order to develop effective improvement programs that include preventive maintenance treatments.

As a result of these and other changes impacting transportation agencies, the role of pavement management is changing. In the past, pavement management was primarily considered to be used for assessing and reporting pavement conditions, prioritizing capital improvements, and estimating funding needs. Today, pavement management has the potential to fulfill a much broader (and more significant) role within a transportation agency. In addition to the more traditional roles it serves, pavement management can support an agency's asset management practices by supporting the

development of strategic performance objectives for the highway system. It can also provide a link to maintenance and operations through the analysis of pavement preservation options. And it can provide the pavement performance data required to evaluate and calibrate the mechanistic-based performance models for use within a specific transportation agency.

The successful transition of pavement management into these areas depends on the availability and accessibility of quality data to support an agency's decision processes. Unfortunately, there are a number of agencies that are currently not fully utilizing their pavement management system to support these types of decisions. Therefore, several immediate issues must be addressed to overcome these hurdles and to prepare pavement management for its broader role in the future. Some of the more immediate needs that might be considered are listed below:

- **Providing access to integrated, quality data**: An effective pavement management system depends on reliable, accurate, and complete information. A number of issues arise in determining what information is needed to support pavement management decisions, how to collect the data most efficiently, and how to ensure the quality of the data collected. In addition, different data sources must be integrated so that stakeholders have access to the information most important to their decision processes.

- **Adapting existing analysis tools**: Pavement management systems include analysis models that predict future pavement conditions so that the use of available funding can be optimized. Many agencies are struggling to develop reasonable performance prediction models and treatment rules that represent the full range of preservation and reconstruction treatments. In addition, the existing models do not consider the broad range of factors that agencies want to consider in selecting and prioritizing projects.

- **Communicating pavement management results**: An effective pavement management system provides empirical information that demonstrates the consequences of different investment strategies and programming decisions. However, project selection processes do not always consider the results of a pavement management analysis. Strategies are needed to more effectively communicate pavement management results in ways that resonate with its users.

- **Integrating pavement management into the decision process**: In the end, the degree to which pavement management can be considered successful is largely dependent on the amount of influence pavement management results have on agency decisions. Therefore, methods that strengthen the links between planning and programming, design, maintenance and operations, and other divisions through improved communication, more reliable data, and stronger analysis capabilities are required.

The Federal Highway Administration (FHWA) sponsored the development of a Pavement Management Roadmap to help identify the steps needed to address current gaps in pavement management and to establish research and development initiatives and priorities. This document presents a 10-year Pavement Management Roadmap that can be used to guide new research, development, and technology transfer opportunities that will lead to improved approaches to pavement management. This Roadmap can substantially improve current practices by identifying the existing gaps and needs in pavement management.

The final results of this project are presented in this report, which presents the prioritized list of research, development, and technology transfer opportunities recommended over the next 10 years. The report also documents the process undertaken to develop the Roadmap and the short- and long-term needs statements that were produced. The needs statements included as Appendix B describe the activities recommended as part of the Roadmap, and their associated costs. The needs statements can be used by the FHWA or other research agencies to secure funding to advance the Pavement Management Roadmap. The needs statements are organized by theme and by recommended timeframe (i.e., short-term and long-term).

In addition to this report, a separate Executive Summary was prepared. The Executive Summary is a concise summary of the Roadmap, providing a prioritized listing of the recommended short-term and long-term activities to advance pavement management.

2.0 Roadmap Development

The Roadmap was developed based on stakeholder input obtained during three regional workshops. This section of the report documents the process followed to identify the needs that are included in the final document.

The Development Process

From the beginning, the FHWA intended the development of the Roadmap to be a collaborative process, involving representatives from each of the various stakeholder groups that either use pavement management data, support the use of pavement management concepts, or provide technical assistance or training to current or future pavement management practitioners.

Representatives from several stakeholder groups were invited to participate in one of three regional workshops held in Phoenix, Arizona; Dallas, Texas; and McLean, Virginia. The stakeholder groups that were invited to participate and the targeted number of representatives from each stakeholder group at each workshop are listed below:

- State highway agencies (SHA): 21 to 25 participants.
- Local agencies/technology transfer centers/Metropolitan Planning Organizations (MPOs): 2 to 3 participants.
- Academia: 2 to 3 participants.
- Private Industry (including data collection and software vendors): 3 to 5 participants.
- FHWA: 4 participants.

A total of 87 participants accepted invitations to participate and were able to attend one of the three workshops. A complete listing of the attendees is provided in Appendix A of this report. In addition to FHWA, the participants represented thirty-one SHAs, seven other government agencies (i.e., cities, counties, and Canadian government agencies), thirteen private contractors, and six academic agencies. A Technical Panel consisting of pavement management practitioners from FHWA, SHAs, and academia provided technical guidance throughout the development of the Roadmap. Each workshop included breakout groups that provided an opportunity for the participants to exchange information on a peer-to-peer basis and to collaborate on the identification of research and development needs in this area.

The primary objective of the workshops was to identify research and workforce development needs within ten pre-established focus areas. These focus areas were identified through a literature search and represented topics that have been identified as subjects important to the pavement management community. The ten focus areas selected for discussion during the workshops included:

1. Data collection techniques, equipment, and emerging needs.
2. Data quality.
3. Data storage integration.
4. Performance modeling.
5. Treatment selection.
6. Use of pavement management in the decision process.
7. Changing needs and emerging technology in pavement management.
8. Quantifying the benefits of pavement management.
9. Integrating pavement preservation and pavement management strategies.
10. Institutional issues and other factors influencing the use of pavement management.

Figure 1 illustrates where each of the ten focus areas fit into the overall pavement management process.

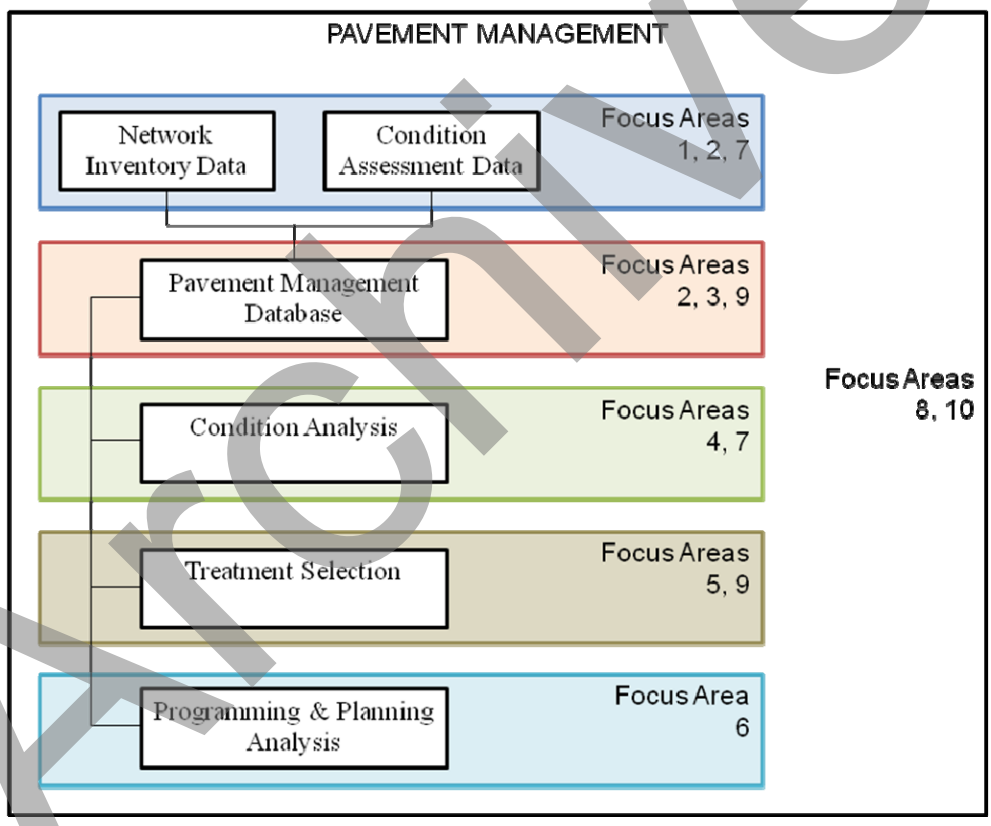

Figure 1. Relationship between Focus Areas and Common Pavement Management Activities.

The participants at each workshop were responsible for identifying gaps in each of the focus areas and for developing both long-term and short-term research, development, and technology transfer needs to address these gaps. The needs statements were documented using a form that records the proposed project objective, description, cost, and duration. A total of 242 needs statements were produced during the three regional workshops. After eliminating duplications and combining statements with similar recommendations, a final list of forty-two needs statements was produced, with a heavy emphasis on short-term needs. Therefore, the Technical Panel was reconvened to identify additional long-term needs statements. The meeting resulted in five additional needs statements, which brought the total number to forty-seven. Each of the needs statements is included in the final Pavement Management Roadmap and is documented in full in Appendix B of this report.

During the process of combining and re-arranging needs statements, it became evident that many of the needs statements impacted several of the ten focus areas. As a result, it no longer seemed practical to tie the final needs statements to the original focus area topics. Instead, the resulting needs were organized and grouped into one of the following four themes that emerged from the process:

- Theme 1: Use of Existing Tools and Technology.
- Theme 2: Institutional and Organizational Issues.
- Theme 3: The Broad Role of Pavement Management.
- Theme 4: New Tools, Methodologies, and Technology.

The final list of needs was presented to the workshop participants during a webconference, which introduced the four theme areas and the balloting process that would be used to rank the needs in terms of importance. Using an online balloting tool, individuals who had attended the workshops were invited to vote on the relative importance of each of the research needs. In addition, participants were asked to rank both the short-term and long-term needs within each theme area. A process was developed for combining the relative importance of each need statement with the rankings assigned by the participants, which resulted in the final prioritized listing of short-term and long-term needs included in the Pavement Management Roadmap. In addition, by having ranked the needs statements within each theme area separately, the highest priorities within each theme, as well as their overall importance across themes, could be produced. The final Pavement Management Roadmap is included in the next chapter of this document.

Needs to be Addressed by the Pavement Management Roadmap

Although the final Pavement Management Roadmap is organized by themes, the stakeholder discussions during the three regional workshops identified gaps within each of the original focus areas. A summary of the state of the practice, the challenges that agencies are facing, and the needs identified during the workshops, is included in this section of the report.

Focus Area 1 – Data Collection Techniques, Equipment, and Emerging Needs

State of the Practice

Data collection techniques, equipment, and emerging needs comprise one focus area that has received considerable attention over the last several decades. This emphasis is due to the need to be able to rapidly collect and accurately characterize pavement condition data, which serves as the basis

for reliably predicting network pavement conditions, recommending rehabilitation or preservation treatment types and timing, and supporting the increasing needs of asset management. In the last several years, there have been a number of advancements in the technology used to collect data (e.g., changes in sensors and image quality) that have impacted the types of pavement condition data that can be collected rapidly and the consistency in data from one year to the next. However, most agencies continue to rely on rutting, ride, and surface condition to support their pavement management activities.

One area of data collection that has seen considerable advancements is automated pavement condition assessment. Due to technological advancements, the assessment of pavement condition has transformed from laborious manual procedures to high-speed automated or semi-automated surveys that combine the use of sensors and digital images. Although the use of high-speed equipment has improved measurement accuracy, shortened the required time for data collection, and improved the safety of the rating crew, there is little consistency among states in how the data are collected and processed. The costs associated with the use of this technology are high, making data collection one of the most expensive aspects of pavement management. Therefore, several agencies are attempting to combine the data collection activities of several divisions to reduce redundancy and to maximize the benefit from those expenditures.

Changes in data collection equipment technology and vendors create a unique challenge to pavement management practitioners due to compatibility issues with historical data. In the absence of equations that correlate data from different data collection devices and vendors, pavement management engineers must determine whether historical data can be used to develop deterioration trends or whether the differences in the data prevent the historical data from being used.

On the positive side, changes in technology have provided an opportunity to collect data that could not easily be collected in the past. For example, recent advancements with Ground Penetrating Radar (GPR) have assisted SHAs in estimating pavement layer thicknesses and in conducting forensic studies. Another example of how technology has changed the type of data that can be collected is reflected in the use of moving deflection equipment to characterize pavement structural condition at the network level. Both of these examples illustrate new information that can be used to improve pavement management recommendations but that also have the potential to support the agency's pavement rehabilitation and design activities. This type of information will be increasingly important due to the data input requirements associated with the new Mechanistic-Empirical Pavement Design Guide (MEPDG) developed through the NCHRP and the reassessment of the Highway Performance Monitoring System (HPMS) reporting requirements used by the FHWA to communicate with Congress. There are other emerging needs that are influencing pavement management data collection activities, such as the increased use of preventive maintenance treatments and the focus on sustainable pavements. Therefore, it is appropriate to question whether the information needed to support the development of pavement management recommendations is adequately addressed through the procedures and techniques being used today. For instance, pavement management practitioners will have to determine the cost-benefit of being able to record fine, hairline cracks using high resolution cameras. Additionally, pavement management practitioners should consider whether information, such as oxidation or raveling, that is needed to trigger preventive maintenance treatments should be incorporated into their pavement management data collection efforts.

The last several years have also included initiatives that have attempted to standardize the collection and processing of pavement condition information. The American Association of State Highway and Transportation Officials (AASHTO) worked with the FHWA on the development of provisional protocols for collecting faulting, rutting, roughness, and cracking data on pavements, but there has not been universal agreement or acceptance of these protocols. The lack of standard methods for collecting pavement condition information places a burden on automated equipment vendors but provides state highway agencies with ultimate flexibility in how they collect and process the data. However, the lack of consistency in data collection and processing efforts makes it difficult to compare performance across agencies. Therefore, it may be important to discuss this issue as an industry to determine whether efforts to standardize pavement data collection activities are warranted and, if so, to identify how to move this issue forward in a meaningful way. Critics of past efforts at standardization indicate that agencies typically try to meet too many needs with the standards and end up failing to meet any of the original objectives. As a result, the standards are not meaningful to anyone and become more of a burden than a help.

There have been a significant number of research efforts in this focus area over the years. A summary of some of the subject areas that have been published in the last 5 years are listed below:

- Traffic data collection/axle load spectra.
- Procurement processes for contracting data collection activities.
- Managing digital images from data collection cycles.
- Development of guidelines for profile data, friction data, and, more recently, noise data collection.
- Issues and challenges in using existing data for performance measurement.
- Optimizing data collection procedures.
- Standardization in data collection procedures.
- Monitoring top-down cracking in long-life pavements.
- Techniques for texture measurement.
- Network-level nondestructive testing intervals.

Challenges in Focus Area 1

A number of challenges exist in the area of data collection, equipment, and emerging technologies. One of the biggest challenges, quality control/quality assurance activities, is so important that it has been established as its own focus area (further discussed in Focus Area 2). Therefore, the challenges listed here concentrate on other issues. For instance, pavement management data collection efforts require significant resources on a regular basis. Many SHAs are questioning these outlays and restricting the funding provided for equipment purchases or survey personnel. As a result, pavement managers are forced to evaluate the level of data accuracy needed, the amount of data needed to support pavement management, and the most cost effective method of collecting the information. Coupled with the emerging demands for pavement-related data associated with the HPMS reassessment and the implementation of the new MEPDG software, the pressures associated with data collection activities will likely increase in the next several years.

Another challenge involves the coordination of data collection activities (such as traffic, materials, maintenance, planning, and budget) within a given SHA. Successfully coordinating these efforts requires a common referencing system, similar data collection schedules, and compatible efforts for

efficiently processing the data. These coordination efforts are rarely institutionalized; instead they rely on the efforts of a few individuals to make them happen. Therefore, there is a substantial risk that the coordinated data collection efforts could end if one or more of the key individuals moves into a new position or leaves the agency.

The amount of time required to process data for statewide networks is also a challenge in some agencies, especially if manual activities are involved in the process. In some states, the length of time between delivery of the condition data and the development of project and treatment recommendations is so short that there is not sufficient time to perform quality checks on the data. As a result, credibility issues may arise if errors are later found in the data.

Data consistency and compatibility issues continue to be challenges facing many SHAs. There are significant issues associated with preserving historical pavement condition data through transitions in data collection methodology (e.g., changes from manual to automated methods), changes in equipment, and changes in vendors. For the most part, little work has been done in this area to evaluate the impact of these changes on pavement management recommendations.

Workshop Recommendations in Focus Area 1

Participants in the workshops for this focus area recognized that with the advancements in data technology, the type of equipment used for data collection, and the consistency in data collection and processing activities varied significantly across the United States. Therefore, many of the problem statements addressed the lack of awareness regarding the state of the practice by recommending the development of calibration centers, the identification of best practices for data collection and reporting, and the development of pavement distress standards. Several problem statements also addressed issues that have been under development for a number of years, but still were in need of additional investigation. These topics included the development of a fully automated condition data processing tool and quantifying the benefits of network-level structural deflection testing. Finally, workshop participants noted a need to better quantify surface-related distresses that are typically difficult for a visual pavement condition system to quantify, such as raveling, oxidation, friction, splash/spray, and noise.

The three regional workshops produced a total of twenty-eight research needs, which were later combined into a total of seven problem statements.

Focus Area 2 – Data Quality

State of the Practice

Pavement management is a data-driven activity. Therefore, the reasonableness and reliability of the pavement management recommendations are directly linked to the quality of the data being used for decisions. There are a number of considerations that go into the determination of data quality, including completeness, correctness, validity, consistency, timeliness, and accuracy. Responsibility for verifying data quality is typically shared by both the data collection contractor and the agency. However, if the agency is responsible for collecting the data, all responsibility for data quality resides within the agency.

Managing data quality typically includes activities such as calibrating data collection equipment or inspection teams prior to the start of the surveys, reinspecting representative segments during the data collection process, and verifying the reasonableness and completeness of the data upon

delivery. For pavement management data collection activities, calibration activities typically include collecting data on control sites where a baseline condition is established by the agency. For some types of equipment, such as falling weight deflectometers, calibration may be performed by a regional calibration center. During the production period when surveys are conducted, many agencies perform periodic "checks" on the data by re-inspecting a representative number of sites or by checking results at blind control sites (sites unknown to the data collection vendor). Once the surveys are completed, acceptance testing is often performed by the agency before inputting the data into the pavement management system. Acceptance testing typically checks for obvious errors or inconsistencies in the data and verification of the ratings on a representative sample of the data.

In an effort to promote consistency in data collection activities, a number of data collection guidelines and procedures have been developed. These include, but are not limited to, the following:

- *Long-Term Pavement Performance (LTPP) Manual for Profile Measurement and Processing* – http://www.fhwa.dot.gov/pavement/ltpp/pubs/08056/08056.pdf.
- *Distress Identification Manual for the Long-Term Pavement Performance Program* – http://www.faa.gov/airports/great_lakes/airports_resources/certification_bulletins/media/09-07%20Attachment.pdf.
- *LTPP Manual for Falling Weight Deflectometer Measurements* – http://www.fhwa.dot.gov/pavement/ltpp/pubs/06132/06132.pdf.

The method used to collect pavement condition information has a significant impact on data quality. Data collected using sensors (e.g., roughness and rutting) are typically considered to have less variability than manual distress surveys. Some agencies are able to perform manual pavement condition surveys with very little variability because of the consistency in raters from year to year. Other agencies use automated crack detection programs as a first cut at classifying distress information and then verify the information using semi-automated processes that allow an inspector to view the digital images at a workstation. The variability associated with each of these procedures has been difficult to quantify and compare.

In the last several years, there has been an increased focus on the development of methodologies and tools to promote data quality. For instance, the Oklahoma Department of Transportation developed a computerized tool to perform quality assurance checks on the processed pavement condition data provided by their contractor. The tool automates some of the basic checks on completeness, reasonableness, and consistency and flags sections that might need to be evaluated in more detail. Other SHAs, like the Virginia Departments of Transportation (VDOT) and the Maryland State Highway Administration (MDSHA), have focused on developing formal quality control/quality assurance plans (QC/QA). The process used by VDOT includes an independent outside assessment to validate and verify the data provided by its data collection vendor. MDSHA owns and operates its data collection vehicle but has developed QC/QA plans to ensure data quality. The QC plan includes steps to verify the data, to search for abnormalities, and to check that the data has been saved. The process also includes a subjective assessment of the crack detection process. As part of its QA process, an independent auditor verifies that the QC process was completed and further checks a representative sample of the data. If discrepancies are noted, the data are reviewed to determine whether the problems were caused by systematic errors or whether reprocessing is required.

To help tailor the data collection practices to the uses of the data, the World Bank has introduced the concept of Information Quality Levels for road management. This approach recognizes that there are five distinct levels of data used by transportation agencies ranging from very detailed data used for research to more general data used for reporting key performance measures (such as smooth roads). Each of the various levels of data requires different degrees of data sophistication and data quality. As a result, the expected use of the data has a significant impact on the data quality requirements. Thus, as the use of pavement management data expands to include new applications (e.g., to calibrate the MEPDG performance models), the adequacy of existing QC/QA procedures may need to be evaluated.

One of the important factors impacting data quality is the turnover of personnel within SHAs. Constant turnover of the individuals responsible for performing pavement condition surveys or verifying the quality of data received from a contractor require that ongoing training programs are in place to help ensure consistency in the data from one year to the next.

There have been a significant number of research efforts in this focus area over the years. A summary of some of the subject areas that have been published in the last 5 years are listed below:

- Availability of quality data for performance modeling and treatment selection.
- Reliability of automated crack detection procedures.
- The need for separate and distinct network- and project-level databases to support pavement management activities.
- The effect of uncertainty in distress measurement on performance.
- Quality control and quality assurance plans.
- Profile data variability.
- How accurate does data need to be?
- Impacts of condition assessment variability on life-cycle costs.
- Preserving and maximizing the utility of the pavement management database.

Challenges in Focus Area 2

As pavement managers review, maintain, and update the various data sources that are needed for pavement management, the required level of data quality should be established for each data element. As part of this activity, agencies will have to strike a balance between low-cost efforts that produce large amounts of low-quality data and more costly efforts that produce less data but provide a higher level of data quality. It often falls to the pavement manager to determine what data are needed and what level of quality is adequate for generating pavement management recommendations within existing resource constraints. Unfortunately, there is little information available in the literature to guide these decisions and to quantify the impact of data variability on pavement management decisions.

Resource constraints also have a significant influence on work in this area. Few agencies have the technical expertise to be able to develop QC/QA plans. As a result, they rely on the data collection vendors to have QC plans in place and do very little to verify the accuracy of the data provided. This issue is complicated further by the frequent changes in technology and the added variability in the data caused by equipment changes.

Workshop Recommendations for Focus Area 2

Participants in this focus area identified a number of needs in the areas of data quality and data variability. Specifically, participants noted the need to quantify the uncertainty and risk associated with variability in data collection, budget allocation, and model prediction. Several of the participants suggested linking data quality to the different types of business decisions, implying that more accurate information is needed for more critical decisions. Others suggested the development of guidelines for referencing pavement data geospatially. In addition, participants noted an overwhelming need for the identification and presentation of best practices for improving data quality in terms of collection, processing, and reporting.

Participants identified a total of twenty-four needs, which were combined into two problem statements.

Focus Area 3 – Data Storage and Integration

State of the Practice

With advancements in data collection practices and equipment (e.g., digital images for pavement condition surveys, transverse and longitudinal profiles, GPR, and moving deflection) comes a significant increase in data storage needs. Within the last decade, pavement management systems have required servers capable of storing terabytes of data, and storage needs will continue to increase with the development and implementation of new technologies. Not only must SHAs deal with how to store these data (e.g., multiple platforms, multiple servers, off-site backup, and potential purging of raw files), but agencies must also address how to manage, update, enhance, and share the information with other divisions within the agency.

Integration and sharing of data among agency divisions can be problematic, especially if a common referencing system is not used. Typically, the pavement management system is comprised of data obtained from various divisions within an SHA (e.g., traffic, materials, construction, and planning). The ability to associate all data with a given roadway location is critical to the performance, accuracy, enhancement, and continued use of the pavement management system. For example, having construction test results, such as density and asphalt content for hot-mix asphalt (HMA) pavements, could contribute to the improved prediction of early failures or help ensure improved pavement performance on a specific roadway segment.

With the development and potential implementation of the MEDPG, the ability to store, link, and retrieve the large magnitude of input and generated pavement design data would fit well within a pavement management system. Data already contained within a pavement management system, such as traffic data, pavement performance data, and existing layer thickness, are needed for calibration, verification, and operation of the MEPDG. As part of the AASHTO DARWin-ME solicitation, AASHTO is making a number of modifications to the software, one of which is establishing an input library database, which could easily be integrated with an SHA pavement management system. If these databases were integrated, SHAs could evaluate the performance of different pavement designs based on differences in materials, climate, traffic, and other design inputs.

Data integration issues are increasingly important in SHAs as agencies move away from independent "silos" for managing information towards a more integrated asset management approach. The ability to share information allows agencies to better coordinate their decisions, reduce data

collection and management costs, and improve the accuracy and timeliness of information. There are a number of different approaches that can be taken to integrate data, including strategies that rely on a centralized database (e.g., a data warehouse) or strategies that use integrated databases that hide the complexity and distribution of the underlying databases. The organizational structure of the agency, the reliance on legacy systems, and the level of resources available to address data integration issues all influence the approach selected by the agency.

An agency's data integration activities influence the format in which pavement management data must be reported. As new data become available, such as GPR or structural information, pavement managers must address formatting issues to maximize the use of the information by the agency.

The application of geographic information systems (GIS) and geospatial technologies to support asset management decision making is reported to be a primary interest area among SHAs. However, the development of these spatial products on an enterprise basis continues to be a challenge for agencies. Therefore, a peer exchange on this subject will be conducted in 2010 to identify the challenges that hinder progress and to propose practical solutions for SHAs. The California, Washington, and Virginia Departments of Transportation have reportedly made substantial progress in this area.

A summary of some of the subject areas that have been published in the last 5 years are listed below:

- Location referencing systems.
- The use of GIS (and other spatial technologies) for data integration.

Challenges in Focus Area 3

As discussed previously, a number of challenges exist in the area of data storage and integration. The pavement manager is faced with determining how data will be stored, how best to share the data with other divisions within an agency, how to obtain needed data from other divisions, and how to maximize the usage of pavement management information within the agency. The challenges include both organizational and technical issues that must be addressed.

Organizationally, the agency structure (i.e., centralized or decentralized) influences the approach that may be used to integrate data. Information technology divisions can also have a significant influence on how easily new programs and new technology can be implemented within the agency.

There are also technical challenges that pavement managers must address. For instance, automated data collection images require extensive amounts of storage. As a result, agencies must decide how much of the data to keep for historical purposes. And, as emerging technology becomes available for pavement management's use, strategies must be developed for integrating that data into the existing systems.

The use of pavement management for calibrating the MEPDG software also poses a challenge for pavement managers because new data inputs must be managed. Agencies will have to decide whether those inputs will be incorporated into a pavement management database or whether there will be new, integrated databases created to link to pavement management performance data.

Similar considerations must be made for integrating preventive maintenance treatments into a pavement management system. Without integrated maintenance data, it is difficult for pavement

managers to determine the performance of preventive maintenance treatments or to evaluate where excessive maintenance expenditures have been made.

Workshop Recommendations for Focus Area 3

Participants in this focus area addressed issues related to best practices for data storage with respect to capacity, organization, security, cost, and purging of historical data. In addition, a number of needs were identified in the area of data mining, focused specifically on how to use and leverage pavement management data for nontraditional purposes (e.g., asset value, new design procedures, impact of improved materials, or construction practices). The participants also identified research into strategies for addressing institutional issues associated with data management, including purchasing policies and controls.

Participants identified a total of eighteen needs, which were combined into three problem statements.

Focus Area 4 – Performance Modeling

State of the Practice

Performance modeling is one of the primary functions of a pavement management system. Pavement deterioration results from the complex interaction between such things as traffic, climate, materials, layer thickness, layer type, and construction practices. Performance models are developed to take these factors into account and predict pavement condition over time, which in turn can be used to predict overall network level conditions, identify treatment needs, select appropriate timings for different treatments, identify funding levels needed to achieve performance targets, and demonstrate the consequences associated with different investment strategies.

There are four broad categories of pavement performance models: deterministic, probabilistic, expert or knowledge-based, and biologically inspired models. The way a model will be used influences the selection of model type. The most common approaches used for network-level pavement management include deterministic and probabilistic models. The most recent research has focused on the use of biologically inspired models that include the use of genetic algorithms and/or artificial neural networks. The use of genetic algorithms results in models developed through an iterative process that mimics evolution. For example, a model is developed for a set of data. Based on the fit of the data, a new population is created from the original population by reproducing, crossing over, or mutating the original data. This evolution continues until an acceptable model is developed. Models developed using artificial neural networks are slightly different in that the models continue to evolve and improve through a computerized process. To date, these models have primarily been used by researchers, but there is potential application for use by the pavement management community.

The information used to develop performance models vary by agency. In general, state highway agencies use the family modeling approach in which pavement sections are grouped by characteristics such as pavement type, structural composition, geographic location, and traffic level or functional classification. Rates of deterioration are determined for each pavement family and the models are typically used to predict pavement condition indexes for indicators such as ride, structural condition, and functional condition; however, there are exceptions to these generalizations. For instance, the Minnesota Department of Transportation models individual distress progression to calculate future surface ratings. Other agencies, such as the Washington State

and Colorado Departments of Transportation, develop individual performance models for each pavement section as long as there are three to five data points that show a reasonable deterioration trend. Where sufficient data points are not available, family models or default models are used.

Much of the attention in this area in recent years involves the use of pavement management data to calibrate and validate the performance models in the new MEPDG software. The use of pavement management data for the calibration of these models has prompted research into the availability of the necessary design inputs in pavement management and the development of strategies to address capabilities that do not currently exist. It has also prompted discussions about the eventual use of the MEPDG performance models and whether they will replace network-level pavement performance models in the pavement management system or whether both types of models will exist in the future.

A related discussion is taking place at the national level where research has led to the development of simplified MEPDG models that have been incorporated into an analysis tool that allows the FHWA to report pavement needs to Congress. The new models have prompted changes to the data requirements needed to support the Highway Performance Monitoring System (HPMS) that will be initiated in 2010.

The FHWA has announced the release of a new tool that can be used to determine the health of a pavement network using a Remaining Service Life (RSL) concept. The primary input to the tool is HPMS 2010 data, but pavement management data can also reportedly be used to support the analysis. Pavement health is evaluated in terms of pavement life, ride, or distress under various environmental and administrative conditions. The tool was demonstrated at the 8th National Conference on Transportation Asset Management in Portland, Oregon in October 2009.

Another initiative that is influencing the development of pavement performance models is the consideration of climate change, green initiatives, and sustainability in transportation agencies. Pavement managers of the future will likely have to consider how these factors can be taken into consideration in developing and refining pavement performance models. There are other industry changes that impact predicted pavement conditions, including increased truck weights and changes in construction materials and pavement design. It is not clear how well these types of initiatives have been considered in pavement management performance models in the past and what expectations there might be for the future.

There have been a significant number of research efforts in this focus area over the years. A summary of some of the subject areas that have been published in the last 5 years are listed below:

- Modeling techniques.
- Effect of initial condition on performance.
- Family modeling versus individual models.
- Project-level versus network-level modeling.
- Probabilistic versus deterministic modeling.
- Modeling individual distress versus indexes.
- Reliability and reasonableness of performance models.
- Database requirements to support performance analysis.
- Impact of distress data variability on model development.

Challenges in Focus Area 4

Pavement performance is influenced by many different factors, some of which are difficult to model. As a result, it is difficult to develop pavement performance models that predict future conditions with a high degree of certainty. It is especially difficult to develop models that reflect the ongoing changes that impact pavement design and construction. For example, this challenge has been demonstrated recently with the impact of Superpave mix design (and the use of modified binders) on the performance of HMA pavements. Many states have over 20 years of performance with Superpave mixes, but few agencies can report with certainty the effect these mixes have had on pavement performance. Similarly, the use of alternative materials and processes (e.g., crumb rubber asphalt, warm mix, two-lift concrete, and hot and cold in-place recycling) may also impact the accuracy of performance prediction. Moreover, the introduction of new materials means that long-term performance data are simply not available, which makes it difficult to forecast the future performance of those materials.

Many states are faced with addressing tire-pavement noise issues, which can have a significant societal impact, but certainly has not been incorporated in existing performance prediction models. Other factors include the impacts of climate change, use of sustainable materials, and modifications to truck weights (a current truck lobby is requesting an increase in maximum weight for trucks on interstate highways from 80,000 pounds to 97,000 pounds). The degree to which these factors should be considered in pavement management performance models and the development of a process to do so (while maintaining consistency in the measures reported to upper management and elected officials each year) certainly presents a challenge to pavement managers. Agencies in Canada are reportedly evaluating risks associated with climate change and the potential impact on transportation needs.

Another challenge facing pavement managers is addressing the question of how the performance prediction models contained within the MEPDG should or will interact with the existing pavement management performance models. It is unclear whether the MEPDG models will replace network-level family models in the future, or whether there is a need to maintain these models separately since both types of models serve different functions.

Even without these types of influences, pavement managers continue to face the challenge of developing reliable performance models using the information currently available. A significant dilemma for many agencies is trying to determine how to improve the reliability of these models in the absence of good information on pavement structure and treatment history. Other agencies acknowledge that pavement management models are "good enough" at the network level, even though they may not be sufficiently accurate at the project level. However, it is worth considering whether this viewpoint will withstand the test of time as computer capabilities evolve and better data become available through improved integration efforts.

Lastly, pavement managers must determine the influence of maintenance as performance models are developed. Some agencies assume that the "do nothing" models incorporate some level of maintenance to help ensure that the expected design life is achieved. However, if pavement management systems will be used to identify candidates for preventive maintenance, the performance of these treatments must be differentiated in order to calculate a benefit associated with its use. This need poses a challenge to pavement managers when preventive maintenance

treatments can be used in both a preventive manner and as a stop-gap treatment to keep a highway section operational until funds become available for more substantial repairs.

Workshop Recommendations for Focus Area 4

Participants in this focus area identified a strong need to establish best practices for modeling pavement performance. At least fourteen needs statements addressed topics related to performance modeling, spanning topics such as the level of detail needed to produce accurate and reliable models; strategies for updating models to reflect changes in material properties, construction, or design practices; and procedures for evaluating the sensitivity of inputs on model prediction. Another area that the participants identified as a need was the use of pavement management information for national reporting, specifically related to HPMS. Finally, participants noted the need to investigate areas related to the use of a performance measure related to structural condition, a need to more accurately design and predict performance on low volume roadways, and a need for a tool that more easily quantifies performance impacts due to increases in legal load limits.

Participants identified a total of thirty-two needs, which were combined into seven problem statements.

Focus Area 5 – Treatment Selection

State of the Practice

The use of pavement management to recommend pavement treatments can vary from state to state. Some agencies determine treatment timing within the pavement management system but determine the treatment type independently; some apply a simplistic list of treatments (e.g., preventive maintenance, functional improvement, and structural improvement); others have developed elaborate decision trees that base treatment type and selection on factors such as pavement condition at time of treatment, prior treatment, pavement type and structure, functional class, and traffic volume. In addition, treatment type and selection can be based on other nonpavement related factors such as safety, noise, combining adjacent projects for economy of scale, delaying projects due to future planned projects, and public pressure.

The process for treatment selection within the pavement management community continues to evolve, as some SHAs are moving in a direction to obtain more data to support the treatment selection process, while others are generalizing the recommendations provided by pavement management so the districts and regions have more influence in the final treatment selection using locally known factors and considerations. The agencies that are looking to enhance their treatment recommendations are considering data not previously available as part of the pavement management process, such as surface texture characteristics, noise, road safety, and structural condition. These additions acknowledge the fact that pavement distress information alone is not sufficient to accurately project current and future pavement needs.

At the same time, some agencies are moving in an opposite direction, modifying their pavement management analysis to be more general about the types of recommendations being made. For instance, one SHA recently moved towards recommendations regarding the level of treatment required rather than attempt to determine the specific type of treatment required; the final treatment selection decision is made by the Regions. In this particular SHA, Regional Pavement Management Engineers have copies of the pavement management software to help with the treatment selection

process, but few reportedly have a strong degree of confidence in operating the software and instead rely on reports from the central office or their own field inspection results.

A factor influencing the reasonableness of the costs associated with pavement management recommendations concerns the number of add-ons required for a project. A pavement management analysis typically calculates only the cost of the pavement improvement, although the cost of some projects can escalate considerably when roadway hardware improvements, American Disability Act enhancements, and safety issues are addressed. The degree to which these costs are considered in a pavement management system varies among SHAs.

Most of the recent efforts in this area are concerned with the incorporation of preventive maintenance treatments into the analysis. The degree to which preventive maintenance treatments can be recommended by pavement management is largely dependent on the availability of the types of information that trigger these treatments and the ability to model performance so that benefits are calculated.

There have been a significant number of research efforts in this focus area over the years. A summary of some of the subject areas that have been published in the last 5 years are listed below:

- Integration of preventive maintenance treatments.
- Consideration of traffic, structure, and other factors not commonly used.
- Sensitivity of treatment timing.
- Effect of initial conditions on performance.
- Integrating road safety data in treatment selection.
- Integrating noise into treatment selection for urban areas.
- Budgetary impacts.
- Optimizing operational and capital expenditures.
- Relating pavement management to maintenance standards.
- Sensitivity of design parameters to optimal maintenance decisions.
- Use of pavement management to support maintenance activities.

Challenges for Focus Area 5

One of the challenges faced by pavement management practitioners is determining when and how to incorporate new treatments into the analysis process or how to update the decision factors used on existing treatments. Many times, this process requires collecting performance, material, and construction data for the development of performance models, but it also requires a process for tracking where these treatments have been used. Since this information is often the responsibility of someone outside pavement management, it is difficult to obtain this type of information on a consistent basis.

There is also a challenge associated with developing the models needed for treatment selection, especially when a treatment has not been used extensively in the agency. Determining how to quantify differences in treatment performance can be difficult and often requires that treatment performance be monitored over time. However, as the industry discovered from the use of Superpave mixes, the location of specific project sections where changes in mix design have been used are not frequently known by pavement management.

Similar types of challenges exist in trying to develop rules for triggering preventive maintenance treatments. Since pavement management was originally developed to identify and prioritize rehabilitation and reconstruction activities, most pavement condition survey procedures focus on capturing substantial amounts of pavement deterioration. In many instances, the information needed to trigger preventive maintenance treatments effectively is not being collected on a network-wide basis so it cannot easily be incorporated into the treatment rules.

It is also difficult for agencies to accurately estimate the costs associated with treatments because of rapidly changing prices and the scope changes that can occur before construction starts. This demands that pavement management evaluate the number and types of project add-ons that can be incorporated into the treatment selection process. For example, some agencies identify shoulder and lane width into their pavement management system so they can determine whether current standards are met before recommending an overlay in the pavement management system. However, not all pavement management systems have been designed to evaluate these needs.

Workshop Recommendations for Focus Area 5

Workshop participants identified the need to summarize best practices for evaluating the decision factors used in the treatment selection process, including both pavement preservation and rehabilitation. In relation to budgeting, the participants felt that having a best practice document that provided a survey of state procedures for allocating funds based on pavement management data would be beneficial. Other suggestions were provided for minimizing project delays associated with the contracting process and improving the breadth of factors considered in developing project and treatment recommendations. The latter needs statements were focused primarily on improving the match between pavement management recommendations and funded improvement programs. According to the workshop participants, this meant expanding pavement management to consider nontraditional factors such as congestion, sustainability, user costs, and other emerging issues.

A total of twenty-four needs were identified and combined into two problem statements.

Focus Area 6 – Use of Pavement Management in the Decision Process

State of the Practice

Pavement management systems include some type of optimization tool that facilitates the prioritization of current and future needs to make the best use of available funds. Most agencies currently use some form of single- or multi-year prioritization in which feasible treatment options are ranked based on criteria, such as benefit-to-cost ratio or cost-effectiveness. In single-year prioritization, the needs for each year are considered independently, while multi-year prioritization considers the needs in each of the analysis years in unison.

The recommendations from the pavement management system typically serve as the starting point for developing the improvement program. The recommendations from pavement management are used in varying degrees by others involved in the project and treatment selection process. In some agencies, pavement management provides pavement condition information as a reference, while other agencies require that a certain percentage of the final program must match the recommendations from pavement management. The latter approach is used to help ensure that funding is spent wisely especially in a decentralized organization. However, matching criteria are difficult to develop and enforce. As a result, some agencies report that their criteria are so general

that they are essentially useless. Nevertheless, as agencies move towards more decentralized decision making, these types of initiatives may become increasingly important.

There are several factors that are part of the project selection process that are not currently considered by pavement management. For example, a number of agencies, especially those in Canada, are beginning to incorporate risk into their decision processes. In particular, they are considering the likelihood of failure occurring and the associated consequence should it occur. Therefore, a higher priority is placed on those projects that demonstrate a high probability for failure and would have a large negative consequence on the agency if failure occurred. In addition, agencies are evaluating how to take into consideration the contribution of pavement projects on initiatives such as safety, sustainability, and climate change. The anticipated impact of decisions on the users of the highway facilities is utilized largely around the world, but is not a significant part of the project selection process in the United States. There is little information in the literature on strategies that incorporate these factors.

Pavement management is not limited to influencing project selection decisions. In some agencies, it provides the basis for developing long-term strategies that are incorporated into an agency's strategic plan. Other agencies have adopted integrated maintenance management and pavement management software to better link maintenance and operations decisions with capital improvement decisions. Pavement management is an integral part of asset management, because it represents one of the largest agency investments in the transportation infrastructure.

Pavement management provides valuable information to support the development of performance targets and the investment levels required to achieve agency goals. However, this assumes that pavement management is capturing the benefits associated with the investments in the pavement network and that those benefits relate to the performance metrics being reported.

This is not always the case. For example, many agencies have performance targets that identify the percent of the roads in good condition based on ride or pavement distress. This works adequately for treatments such as overlays that have a positive impact on these metrics. However, it may not work as well for preventive maintenance treatments that have little impact on traditional performance metrics such as ride (e.g., crack sealing and chip seals). As a result, it is difficult to quantify the benefits associated with these treatments and to defend the investments being made in these programs. Intuitively, agency engineers know the treatments make sense, but unless the benefits can be quantified and measured, it is difficult to demonstrate that investments in pavement preservation are effective.

Pavement management can also be used for the allocation of funding to address agency needs. Most commonly, agencies use the pavement management system to determine needs on a statewide basis and on a district (or regional) basis. The ratio of the district needs to the total needs becomes one of the primary considerations in allocating funds across the state. However, since this approach presents a financial incentive to have a large percentage of needs, it tends to support districts that may not be practicing sound pavement management practices.

A summary of some of the subject areas that have been published in the last 5 years are listed below:

- Optimization techniques.
- Incorporation of risk and/or probability.
- Multiple attribute optimization.
- Use of genetic algorithms for network optimization.
- Use of monetary factors rather than physical condition performance in program development.
- The effectiveness of needs-based budgeting.
- The role of user costs in an optimization analysis.
- Prioritizing projects based on financial consequences.
- Program effectiveness: are we spending money effectively? How do we know?

Challenges in Focus Area 6

Ultimately, pavement management provides agencies with recommendations for using available funding as effectively as possible. Project recommendations are most often based on maximizing the benefit/cost or cost effectiveness of a program for a given funding level.

However, in real life there is not always a direct correlation between the recommendations from pavement management and the construction projects that are funded. There are many factors influencing the final selection of projects (e.g., political, economic, and technical issues) that indirectly influence the degree of credibility and acceptance of pavement management within an agency. Organizational factors and the degree to which an agency is decentralized also influence the final project selection process.

Therefore, one of the challenges for pavement management is to strike a balance between the development of reasonable project recommendations that influence the construction program and the data requirements needed to support this level of sophistication. Agencies must determine who has responsibility for the final treatment decision and what information should be used to influence its selection. For instance, agencies will have to decide if they want pavement management information to be a primary driver in the decision process or whether it should play a supporting role by providing condition (and other) information to decision makers. Additionally, agencies must decide what factors will be considered in the pavement management analysis and which factors are appropriate to evaluate outside of the pavement management analysis. Because of the differences in the way SHAs operate, no one solution will satisfy all agencies.

An underlying decision in this process is determining where project and treatment decisions will be made within an organization. If the decisions will be made in the districts or regions, then it is more difficult to achieve a statewide performance target. However, if the decisions are heavily influenced by the central office, the districts and regions often fight the recommendations. Moreover, differences in the types of treatments being recommended (i.e., capital projects or maintenance projects) may influence the strategy selected. Ultimately, if project and treatment decisions are being made in the field offices, agencies should determine whether pavement management tools will be required to support these decisions or whether some type of matching criteria are needed to help meet agency-wide goals and targets.

For pavement management to be most beneficial to support asset management decisions, it is important that the analysis results quantify the benefits associated with the options being considered.

Agencies have found it to be difficult to adequately represent the benefits associated with the use of preventive maintenance treatments because the typical types of performance measures that are being reported are not substantially influenced by these treatments. For example, if an agency reports pavement conditions in terms of ride, then investments in chip seals and crack sealing will show little to no benefit (and may actually cause a rougher ride). As agencies are being held more accountable for the way funding is being used, investments in treatments that do not show a benefit may be restricted. This shift may require changes to the types of performance metrics being used in the future, although ride is popular because it is an end-user response and is relatively easy to collect.

Agencies will also be faced with challenges related to improving their allocation of funding across the states. Traditionally, funding allocation decisions have been based on needs, which may penalize districts that effectively use pavement preservation techniques. This type of challenge may be difficult to overcome if the allocation formulas are legislated.

One of the biggest challenges that agencies face is building and maintaining support for pavement management. Unless pavement management is fully integrated into the decision process, some executives may consider pavement management to be a resource that is susceptible to funding cuts. Pavement management concepts are not generally well known at the executive levels so there is a continuous need to promote the concepts and educate decision makers in this area. This effort is time consuming for pavement management practitioners, and most engineers are not comfortable in this environment. And, to date, efforts have not been very effective in communicating in a way that resonates with decision makers.

Workshop Recommendations for Focus Area 6

As in the previous focus area, the participants in the workshops identified a number of research and development areas to support this effort. Suggested topic areas included expanding the factors currently considered in pavement management to include safety, congestion, and environmental factors; user costs; and other emerging issues. A key emphasis of these efforts includes addressing institutional issues that commonly prevent the use of this information, such as organizational structure, industry pressures, risk considerations, or legal issues. Several needs statements also addressed the consideration of risk, variability, and uncertainty in pavement management data and their impact on pavement management recommendations. There were also a number of suggested needs statements oriented towards strengthening the link between pavement management inputs and performance targets.

Many of the problem statements in this area supported the need for increased emphasis on developing the skills of pavement management practitioners and increasing buy-in among internal and external stakeholders. The topics focused on communication, buy-in, and training were common to most of the focus areas discussed at the workshops.

A total of five needs statements were produced from the twenty-four problem statements identified during the workshop.

Focus Area 7 – Changing Needs and Emerging Technology in Data Collection and Analysis

State of the Practice

Pavement management capabilities have evolved significantly since the concepts were first introduced nearly 45 years ago. A large part of the evolution is associated with the advancements

that have taken place in terms of computer technology and data collection equipment. Other changes relate to modifications in the materials, treatments, and construction practices being used. This latter set of changes has more of an impact on the types of models and recommendations being used in pavement management than the practice itself.

The data requirements for pavement management are changing as a result of these and other changes. For example, in 2010 new requirements will be in place for reporting HPMS data to the FHWA. Furthermore, as discussed elsewhere in this document, the new MEPDG software is based on a large number of inputs and requires calibration of the performance models to reflect agency performance, and agencies will be examining ways to employ pavement management data to calibrate the procedure for their pavements.

At the same time, agencies are increasingly using performance measurement as a way to monitor progress and to establish agency goals. These metrics influence the allocation of funding and are frequently used to establish agency priorities. Therefore, pavement management systems must collect and report performance data that supports the analysis of these metrics.

The types of analyses being performed using pavement management tools are also changing. While traditional pavement management systems consider pavement improvements on a section-by-section basis, several SHAs with heavily congested urban areas are demanding that entire highway corridors be analyzed and managed.

Changes in contracting procedures have also influenced the data required of pavement management. Specifically, the increased use of public-private-partnerships and performance-based specifications have forced agencies to develop means of collecting defensible information that can be used to define payouts, including incentive and disincentive clauses.

There have been a number of research efforts in this focus area over the years. A summary of some of the subject areas that have been published in the last 5 years are listed below:

- Calibration of the MEPDG.
  - — Securing the data needed for calibration of the performance models.
  - — Material testing and field performance studies in support of the MEPDG calibration.
  - — Implications of uncertainty in distress measurements on model calibration.
- Establishing performance measures for Public Private Partnership (PPP) contracts.
- Use of pavement management data to monitor pavements under warranty.

Challenges in Focus Area 7

There are a number of challenges that will impact the degree to which pavement management can respond to the changes discussed previously. One of the largest challenges relates to the availability of the data and expertise needed to support these initiatives. This problem is especially true as agencies downsize and the remaining staff are spread increasingly thin in a number of different program areas. Developing a skilled workforce that has the technical expertise required to adapt to these changes will be increasingly difficult.

Another challenge involves national efforts to increase consistency in the way pavement condition information is measured and reported. Several significant efforts are moving in the direction of

using consistent measures (e.g., MEPDG and HPMS), but it is unclear whether SHAs will modify their historical data collection methods, supplement their existing approaches with information to satisfy the new initiatives, or ignore the requests to report data in a certain way. What is clear is that until there is more consistency in data collection procedures, it will continue to be difficult to meaningfully report pavement conditions on a national basis. Whether this has been part of our communication problem has yet to be debated.

SHAs are also challenged by their ability to use traditional pavement management software to analyze different funding scenarios quickly and efficiently. In many instances, agency management needs the results of a "what if" scenario in a very short period of time, which is often difficult to accomplish depending on the complexity of the pavement management system. Being able to quickly provide meaningful results may require different tools than those currently being used for project and treatment selection activities. In addition, it is difficult for some agencies to isolate the needs of highway corridors because of the way most existing pavement management systems analyze sections independently.

Workshop Recommendations for Focus Area 7

Participants in the workshops identified research and development needs that would enable pavement management to be more responsive to the new technologies that have emerged in recent years. For example, suggested needs involved the development of a general process for incorporating emerging technology into a pavement management analysis. More specifically, several of the groups suggested that research efforts focus on supporting innovative contracting, automated condition data processing, pavement design, and data mining (to better leverage the use of pavement management data). Additional needs focused on improving pavement condition data quality and reporting.

In addition, workshop participants suggested that studies be conducted on quantifying the benefits associated with pavement research and quantifying the costs and benefits associated with "pay per use" strategies. The first of these two initiatives provides a mechanism for documenting the on-going benefits associated with research activities. The second recognizes the changes that are expected to take place in transportation funding and prepares pavement management practitioners for these adjustments. In addition, several of the participants suggested that a synthesis study be conducted to evaluate how transportation agencies have successfully responded to the changing environment in the past so that effective strategies can be identified for use by others. Finally, participants recommended research into the use of new technology, such as social networking, to communicate with practitioners. A total of nine research needs were developed from the original list of thirty-two.

Focus Area 8 – Quantifying the Benefits of Pavement Management

State of the Practice

Pavement management is an expensive and labor-intensive proposition. Agencies support pavement management efforts through investments in personnel, software, and on-going data collection activities. There are annual costs associated with the maintenance of software licenses and data collection efforts. Agencies that own their own data collection equipment must upgrade on a regular basis and calibrate the equipment regularly. There are also on-going training requirements as pavement management staff change and as new technology becomes available.

While it may be possible to capture most of the costs associated with pavement management, it is much more difficult to quantify the benefits associated with these programs. For the most part, pavement management has promoted subjective benefits such as improved decision making, better use of available funds, and improved communication. At least two agencies, including the Arizona Department of Transportation and the Alberta Ministry of Transportation, have conducted studies to quantify the benefits associated with pavement management by attempting to document the cost effectiveness of the programs. Both studies quantified benefit in terms of the improved conditions associated with the use of pavement management software and compared the benefits to the costs of software, data collection, and personnel. These studies provide the foundation for quantifying the benefits associated with pavement management, but more rigorous approaches are needed to convince decision makers of the benefits to pavement management. Alternative approaches that demonstrate the return on the investments made in pavement management show promise.

Some of the benefits that an agency may realize from pavement management extend beyond improved pavement conditions. For example, some agencies have been able to demonstrate improved surface texture characteristics that have reduced the number of wet-weather crashes or reduced noise levels leading to improved customer satisfaction. However, these types of benefits are not easily quantified on a network-wide basis as part of a pavement management analysis. They are typically investigated outside of pavement management by other divisions.

There have been a significant number of research efforts in this focus area over the years. A summary of some of the subject areas that have been published in the last 5 years are listed below:

- Documenting the benefits of pavement management.
  — Impact on network condition level.
  — More effective use of funds.
  — Better decisions (understanding consequences).
  — Improved communication.
  — More objectivity and transparency in the decision process.

Challenges in Focus Area 8

Perhaps the greatest challenge in this area is quantifying the benefits associated with pavement management. At least two researchers have initiated efforts in this area by quantifying the dollars saved through the use of improvement programs that are more effective than the traditional "worst first" strategies that place the highest priority on pavements in poor condition. However, researchers have found it difficult to quantify the costs and benefits associated with pavement management and the metrics used have not resonated with executives and other decision makers. As a result, the industry has relied on promoting subjective and anecdotal evidence of benefits. Developing strategies to address these shortcomings may be beneficial to the industry.

Closely related to the inability to estimate benefits is the difficulty in quantifying the benefits associated with increased investments in pavement management. For example, if $300k is currently being spent on data collection activities, what would an additional $100k investment provide? Would it lead to better quality data? Would it allow the agency to verify the quality of the data provided by a vendor? Would it lead to a reduced risk to the agency? What economic benefit does an increase in network conditions provide? The answers to these types of questions are not well understood, making it difficult to defend budget recommendations or changes in technology.

Another challenge facing pavement management is the lack of a catch phrase that emphasizes its benefits. For example, the pavement preservation community has relied on its slogan "right road, right treatment, right time" to communicate its objective. There is no such phrase for pavement management to quickly communicate its purpose (although the pavement preservation slogan would certainly fit).

Workshop Recommendations for Focus Area 8

Due to the absence of clear processes for calculating the benefits associated with pavement management, the workshop participants identified needs statements to develop methods to quantify the benefits of pavement management and the information it provides to various stakeholders. In a related area, participants suggested that research investigate the impact of different investment levels in pavement management on the quality of the recommendations provided. This information was considered to be important for promoting continued financial investment in pavement management. Once processes are developed to quantify benefits, participants suggested the development of strategies to promote pavement management as a decision support tool using public relations campaigns and other approaches.

The remaining needs statements focused on the availability of information to support pavement management. For instance, participants suggested a clearinghouse for better access to available resources, pavement management courses in civil engineering curriculums in colleges and universities, and independent technical assessments to help agencies enhance existing capabilities.

The original twenty problem statements in this focus area were condensed into five.

Focus Area 9 – Integrating Pavement Preservation and Pavement Management

State of the Practice

In recent years there has been tremendous momentum for the increased use of preventive maintenance treatments as an important component of a cost-effective pavement preservation program. However, there is little quantifiable evidence of the benefits of preventive maintenance treatments because most pavement management systems are unable to adequately quantify the benefits using existing metrics. As a result, most agencies rely on anecdotal evidence that pavement preservation makes sense and benefits an agency in terms of reduced life-cycle costs, improved pavement performance, and improved safety characteristics. Efforts to demonstrate the benefits associated with these programs have proven to be difficult, in part because the performance metrics used to report network health (such as ride) are not always improved through the use of preventive maintenance treatments. Therefore, some agencies have identified the need to develop and implement new types of performance metrics that better capture the benefits provided by strong pavement preservation programs that include the use of preventive maintenance treatments.

Another complicating factor that hinders efforts to quantify the benefits of effective pavement management is the separation of pavement management and pavement preservation within the agency. In many SHAs, pavement management and pavement preservation efforts are separate initiatives performed by different divisions. Some agencies have attempted to bridge these divides by creating a Pavement Preservation Engineer position that is based in the Maintenance and Operations Division with collateral duties that include coordinating with the Pavement Management Unit. In agencies with strong pavement preservation programs, this is a popular model to follow.

The industry has also supported the separation of pavement management and pavement preservation activities through separate conferences, separate teams within FHWA, and separate committees within the Transportation Research Board structure. However, because of travel restrictions, budget constraints, and increased efforts to streamline organizational activities, agencies are beginning to question whether it continues to make sense to keep these activities separate. These agencies see pavement preservation as little more than an effective pavement management strategy. Therefore, the need for separate programs is difficult to support.

At the same time, the FHWA is initiating efforts to increase the profile of pavement management by emphasizing "the management of pavements" more than the use of a computerized software program. This places more of an emphasis on the role of pavement management within the organization to support decision making and less of an emphasis on the data collection activities that many associate with pavement management. The long-term effect that this shift will have on pavement management, and the ultimate success of changing pavement management's profile, is unknown at this time.

At the same time, there are some inherent issues with existing pavement management process that may be limiting an agency's ability to demonstrate the benefits of preventive maintenance treatments. For instance, not all pavement condition surveys adequately address the types of deterioration that trigger the need for preventive maintenance treatments. Few agencies are initiating efforts to change their data collection procedures to better identify preventive maintenance triggers.

The use of preventive maintenance treatments is not currently considered in the MEPDG software, although some research has been conducted to develop a framework for doing so. The absence of these treatments in the design software has led some researchers to question whether the use of preventive maintenance treatments are assumed as part of the original design life, or whether they should be considered in the same manner as other treatments (i.e., overlays) as extensions to the original design life.

There have been a significant number of research efforts in this focus area over the years. A summary of some of the subject areas that have been published in the last 5 years are listed below:

- The economics of pavement preservation.
- Demonstrating the benefits of pavement preservation.
- Cost benefit of preservation strategies versus reconstruction.
- Determining life expectancies of preventive maintenance treatments.
- Links between pavement preservation guidelines and pavement management treatment rules.
- Safety effects of preventive maintenance.
- Integration of preventive maintenance into the MEPDG.

Challenges in Focus Area 9

As previously discussed, it has proven difficult to quantify the benefits associated with the use of preventive maintenance treatments as part of a pavement preservation program. This is due, in part, to the lack of performance data on preventive maintenance treatments. Because of the types of pavement condition data normally collected during network level surveys, the benefits associated with preventive maintenance treatments, such as surface sealing to prevent moisture infiltration or

oxidation, are not currently captured or quantified. As a result, it is difficult to defend the continued expenditure of funds on preventive maintenance programs.

Another challenge facing the pavement management community is the continued distinction between pavement preservation and pavement management. These programs are often represented separately by industry, and they are managed by different divisions within a SHA. There is increasing support for promoting pavement preservation as an effective pavement management strategy, but that may be difficult to adopt in agencies where these programs are considered to be separate and distinct. As long as there continues to be some confusion in the differences between pavement management and pavement preservation, both programs will struggle with establishing their identities and building support within the industry.

Ultimately, pavement management practitioners must determine the role of preventive maintenance activities in the management of pavements. For instance, is the use of planned maintenance activities a requirement for pavements to reach their design life, or are these treatments applied to extend pavement life beyond the original design period? The answer to this question may have a significant influence on how preventive maintenance treatments are considered in a pavement management system.

Workshop Recommendations for Focus Area 9

Participants in this focus area recognized that some work has been done in an attempt to integrate preventive maintenance treatments into a pavement management system, but suggested that additional activities be conducted to further the consideration of early-intervention treatments in a pavement management program. Specific suggestions related to the quantification of costs and benefits associated with preventive maintenance treatments, the identification of appropriate intervention levels, and the development of guidelines for agencies seeking assistance in this area.

In addition to the development of general guidance, workshop participants identified the need to determine the impact of preventive maintenance treatments on pavement performance to help identify the optimal timing for these treatments. Additional needs statements addressed strategies for communicating the benefits of pavement preservation, supporting pavement preservation funding levels, and developing effective performance measures to support pavement preservation.

The three regional workshops produced sixteen needs statements, which were later combined into two topics.

Focus Area 10 – Institutional Issues and Other Factors Influencing the Use of Pavement Management

State of the Practice

As technology, construction practices, and organizational policies and programs change, pavement management must continue to evolve to reflect the impact of these changes on project and treatment recommendations and priorities. Without the ability to adapt to these changing influences, pavement management will not survive.

Focus Area 7 concentrated on the changing needs and emerging technology that will influence pavement management in the future. In this focus area, the institutional issues and national initiatives expected to influence pavement management were addressed. This provided an

opportunity for workshop participants to identify other types of emerging trends that may influence pavement management 5 to 10 years into the future.

For example, a number of agencies have placed an increased emphasis on the use of asset management principles to guide investment allocation decisions and to establish performance targets. Exactly what role pavement management will have in supporting investment allocation decisions is not known, but it is clear that pavements and bridges lead other assets in terms of the data available to support the agency's asset management efforts. Some agencies have created separate asset management divisions, which are responsible for the data collection activities needed to acquire inventory and condition information. Other agencies have not changed the organizational structure but created executive committees that combine the recommendations from each asset class to determine a final program. The movement towards the increased use of performance measures and asset management principles is expected to place more of an emphasis on pavement management results in the future. However, it is not clear whether pavement projects will compete favorably with other projects in an asset management environment.

Over time there has also been an increased focus on being able to compare performance from one agency to another as part of benchmarking activities. Most recently, there has been a great deal of interest in the performance metrics being used by SHAs to determine whether there are common measures that should be reported. For instance, NCHRP Report 632 documents a framework for identifying common performance indicators for managing interstate pavements. This has increased the demand for more consistency in data measurement and reporting and exposed the difficulty in getting states to agree on common metrics that may result in compatibility issues with historical data. However, the new HPMS reassessment requirements may cause some states to move in the direction of changing the way some distress information is reported.

Although the technology associated with pavement management has improved tremendously in recent years, there is little evidence that the recommendations are being increasingly utilized. Instead, many agencies continue to rely on political influences and regional pressures as the primary driver of the construction program. The challenge for pavement management practitioners is developing a strategy that makes better use of technology to defend project and treatment recommendations. For example, in criminal cases the legal industry was able to make a monumental shift in the way trials are conducted by introducing DNA evidence. Can a similar shift take place in pavement management using new technology or analytical procedures?

The changes in the availability of funding have also significantly influenced pavement management over the years. While transportation has been funded at inadequate levels for many years, industry organizations are strategizing about new methods of paying for infrastructure improvements. Suggestions for toll roads, increased privatization of portions of the road system, changes to the gas tax structure, and increased funding in the highway bill have all been discussed and debated. States are increasingly finding it difficult to come up with state matches for federal funds and, as a result, have placed more of an emphasis on maintaining the existing infrastructure rather than investing in expansion efforts. Whether these trends will continue and for how long is not known. What is known is that the transportation network will continue to deteriorate if increases in funding and more flexibility in how funding can be used are not provided.

The environment in which pavement management operates has also seen significant changes in the past 20 to 30 years. Many transportation agencies have experienced downsizing, which has resulted

in the significant loss of institutional knowledge. Organizational silos still exist, but there is an increasing amount of interaction between divisions and more data sharing than in years past. This change is largely due to the decreasing availability of funds and the increased pressure to eliminate duplication and to consolidate activities where practical. In many organizations, this sharing of information is not the result of organizational changes to foster improved communication and interaction, but typically results from the initiative of a few key champions.

There have been a significant number of research efforts in this focus area over the years. A summary of some of the subject areas that have been published in the last 5 years are listed below:

- Use of pavement management data to support asset management, including:
  — Investment decisions.
  — Strategic planning.
  — Performance measurement.
- Use of pavement management at the regional level.
  — Use of a common index for regional planning.
  — Use of pavement management tools for establishing regional priorities and project selection.
  — Group purchasing of pavement management software.
- Determining appropriate decision criteria to meet stakeholder needs.
- Strategies for integrating sustainable practices into pavement management.
- Recognizing and moving towards best practice.
- Overcoming challenges to the management of assets (i.e., data quality, technocrats, forward planning, budgeting, and increasing demands).
- Managing change in transportation agencies.

Challenges in Focus Area 10

There are several challenges that must be recognized during the discussion of this focus area topic. For instance, one challenge concerns the participants' ability to forecast future trends accurately in an environment that is heavily influenced by political factors that impact funding, policy, and national initiatives. Another challenge involves developing a strategy that positions pavement management in a way that allows pavement management practitioners to adapt to changes as they occur.

The organizational and institutional changes will also demand that the civil engineer of the future have a broader range of skills than in the past, so workforce development activities must also be identified to address those needs. The decreased availability of funding has impacted agencies' ability to provide workforce development, so nontraditional methods of acquiring these skills will have to be created.

It is also obvious that transportation agencies have not been effective in communicating the need for increased funding to reduce the risk associated with deteriorating pavement conditions. Unless transportation officials are able to find a forum for effectively communicating their needs, it is likely that the existing funding situation will not change. This will place more of a burden on pavement management practitioners to use the available information for an increasing number of purposes.

Workshop Recommendations for Focus Area 10

The regional workshops produced many needs statements intended to evaluate the impact of organizational structure, funding allocations, and earmarks on pavement management recommendations. Others suggested the need to help develop guidelines that would build support for pavement management among agency leaders and field personnel.

Participants in this area also recognized the need for better access to shared resources for pavement management practitioners. Therefore, suggestions for a national pavement management partnership were offered as one way to provide this knowledge. Other participants suggested constant funding to support pavement management activities and research into pavement management's role in an asset management environment.

A total of twenty-four research and development topics were suggested in this focus area, which were later combined into five needs statements.

Combined Needs Statements Included in the Pavement Management Roadmap

As discussed earlier, duplications within the 242 needs statements developed through the three regional workshops were eliminated, and similar topics were combined to reduce the final number of research, development, and technology transfer recommendations to forty-seven. This total includes twenty-three short-term needs (to be conducted within the next 5 years) and twenty-four long-term needs (that should be addressed in the next 6 to 10 years). The needs statements were later organized by theme, which had facilitated the combination of needs statements that had been suggested under multiple focus areas. The four theme areas included in the Pavement Management Roadmap are summarized below:

- Theme 1: Use of Existing Tools and Technology.
- Theme 2: Institutional and Organizational Issues.
- Theme 3: The Broad Role of Pavement Management.
- Theme 4: New Tools, Methodologies, and Technology.

The final list of needs statements that are included in the Pavement Management Roadmap are presented in tables 1 through 4. Each table lists the short-term and long-term needs identified in each theme area, as well as a summary of the focus area and regional workshop at which the idea emerged.

Table 1. Final List of Research Needs Statements for Theme 1.

Theme 1: Use of Existing Tools and Technology			
Short-Term Needs			
Title	**Contributing Problem Statement Title**	**Originating Regional Workshop**	**Originating Focus Area**
Establish & Develop Equipment Calibration Centers and Guidelines	Calibration Centers or IRI, Rut, and Fault Measurements	Phoenix	1
	Reference Calibration for Profile, Noise, Texture, GPR	McLean	1
	Calibration and Development of Standards	Phoenix	2
	QA Process	Phoenix	2
Pavement Management Clearinghouse	Develop a Continuous Catalog of Data Collection Technology	Phoenix	1
	Develop a National Pavement Management Resource Center	Phoenix	8
	Develop Knowledge Sharing Tools	McLean	8
	Formalize a Pavement Management Partnership to Advance the State of the Practice	McLean	10
	Data Collection User's Group/Peer Exchange	McLean	2
	Establish Contractor Clearinghouse	Dallas	5
Development of Pavement Distress Standards	Best Practices for Standardization of AASHTO Protocols	McLean	1
	Quality Management Standards for Network-Level Pavement Data Collection	McLean	2
	National Standards for Pavement Data – Performance Based Federal Aid Program	McLean	3
	Improving Protocol Design with Advancing Technologies	Dallas	1
	Best Practices of Profile Measurement and Analysis	Dallas	1
Development of Improved Methodologies for Evaluating Data Quality	Definition of Quality Management Principles for PMS Data Collection	McLean	2
	Best Practices for Quality Management	McLean	2
	Communicating Data Quality and Managing Expectations	McLean	2
	Defining Data Quality Requirements for Different Business Decisions	McLean	2
	Minimum Data Quality Standards for Pavement Management Data by Decision Level	Dallas	2
	Development of Pavement Management Quality Guide	Dallas	2
	Develop Techniques to Manage Data from Various Sources and Technology	Dallas	2
	Assessing Data Quality in Data Provided by Non-Agency Sources	Dallas	2
	Issues with Outsourced Information Technology Services	Dallas	3
	Improve Data Collecting and Analysis Consistency	Phoenix	7
	Best Practices for Data Collection and Analysis	Phoenix	7
	Development of More Sophisticated Methodologies for Evaluating Data Quality	Dallas	7

Table 1. Final List of Research Needs Statements for Theme 1 (continued).

Theme 1: Use of Existing Tools and Technology			
Short-Term Needs			
Title	**Contributing Problem Statement Title**	**Originating Regional Workshop**	**Originating Focus Area**
Best Practices Guide for Pavement Management	Impacts of Data Collection Frequency, Reporting on Pavement Decision Making	Phoenix	1
	Outlining Mechanisms to Improve Agency Business Practices	Dallas	10
	Identify Statutory Barriers that Prevent Effective Pavement Management Implementation	Dallas	10
	Best Practices for Data Collection Needs to Support Decisions	Dallas	1
	Best Practices for Disseminating Technology Transfer	Dallas	1
	Effective Use of GPR	Dallas	1
	Guidelines for Referencing Pavement Data Geospatially	Dallas	2
	Data Storage Issues	Dallas	3
	Research to Determine the Level of Accuracy Required	Dallas	4
	Establishment of Feedback Loop	Dallas	4
	Develop Incentives in Budget Allocations for Proper Project Selection	Dallas	5
	Define Performance Curves Using Appropriate Parameters for Pavement Preservation Treatments	Dallas	5
	Create Guidance Document that Defines When and Where to Use Structural Evaluation	Dallas	5
	Pavement Management Influence on STIP, Strategic Plans, and Budget Allocation	Dallas	6
	Effective Communications of PMS Info to Decision Making Process	Dallas	6
	Organizational Effects of PMS	Dallas	6
	Identifying Organizational Components that Lead to Successful PMS	McLean	10
	Advancement in Data Collection Equipment Technology	McLean	1
	Guidelines for Reporting Pavement Management Outputs	McLean	1
	Best Practices for Data Collection and Reporting	McLean	1
	Modeling Impact of Climate Change on Pavement Performance	McLean	4
	Traffic Data Acquisition to Allow Performance Models to be Examined Based on Change in Condition Over Cumulative Loads	McLean	4
	Guidance on Methods for Evaluating and Updating Models	McLean	4
	Methods of Determining Model Reliability and Assessing Level of Reliability Needed at the Network Level	McLean	4
	Guidelines for Picking Best Measures for Your Program	McLean	4
	Guidance on Collecting Data for Changes in Design or Materials	McLean	4

Table 1. Final List of Research Needs Statements for Theme 1 (continued).

Theme 1: Use of Existing Tools and Technology			
Short-Term Needs			
Title	**Contributing Problem Statement Title**	**Originating Regional Workshop**	**Originating Focus Area**
Best Practices Guide for Pavement Management	Synthesis of Best Practices Using Multiple Triggers for a Treatment or Various Treatments of Physical and Environmental Conditions	McLean	5
	Development and Implementation of Best Practices for a Practical, Needs-Based Budgeting Approach	McLean	5
	Responsibility for Project-Level Decisions	McLean	6
	Impact of Organizational Structure on Pavement Management	Phoenix	10
	When to Decide to Abandon Historical Data	Phoenix	1
	Benefits and Limitations of Automated Data Collection	Phoenix	1
	Benefits and Limitations of Network Level GPR	Phoenix	1
	Development of Quality Tolerances Based on Types of Data Collected	Phoenix	2
	How to Store and Purge Safe, Secure, Up-to-Date Pavement Management Data	Phoenix	3
	Effective Communication Issues	Phoenix	3
	Impact of Model Details on Results	Phoenix	4
	Use of Performance Models for Public Relations and Education	Phoenix	4
	Develop a Repository of Models for Use by Other Agencies	Phoenix	4
	Identify Construction and Material Parameters to Fine Tune Treatment Selection	Phoenix	5
	Identify Impact Associated with Staff Reductions and Budgetary Constraints on Treatment Selection at the Network, Project, and Research Levels	Phoenix	5
	Business Process – Allocation of Resources and Strategic Planning	Phoenix	6
	Business Process – Network/Project Level Linkage	Phoenix	6
Synthesis of External Issues Driving Pavement Management	External Influences on Pavement Management	Dallas	6
	Evaluation of External Issues Driving Pavement Management Needs	Dallas	7
Independent Technical Assessments of Pavement Management	Independent Technical Assessments by FHWA	McLean	8
Comprehensive Study to Guide the Integration of Pavement Preservation and Pavement Management	Determination of Required Inputs and Expected Outcomes to Effectively Integrate Pavement Preservation Strategies into Pavement Management	Phoenix	9
	Quantification of Costs and Benefits Associated with Different Levels of Pavement Preservation and Pavement Management Integration	Phoenix	9
	Developing a Plan and Implementation Guidelines for Integration of Pavement Management and Pavement Preservation	Phoenix	9
	Development of Minimum Levels and Best Practices of Integrating Pavement Preservation with Pavement Management	Phoenix	9

Table 1. Final List of Research Needs Statements for Theme 1 (continued).

Theme 1: Use of Existing Tools and Technology			
Short-Term Needs			
Title	**Contributing Problem Statement Title**	**Originating Regional Workshop**	**Originating Focus Area**
Comprehensive Study to Guide the Integration of Pavement Preservation and Pavement Management	Develop a Synthesis for Integration of Pavement Management and Pavement Preservation Practices	McLean	9
	Costs, Benefits, and Risks of Integrating Pavement Preservation into Pavement Management	McLean	9
	Development of Tools and Recommendations for Integrating Pavement Preservation into a PMS	McLean	9
	Define Preventive Maintenance to Include Activities Throughout Pavement Life	Dallas	9
Long-Term Needs			
Title	**Contributing Problem Statement Title**	**Originating Regional Workshop**	**Originating Focus Area**
Investigation Into the Risk, Uncertainty, and Variability in Pavement Management Decisions	Relationships Between Data Quality and Performance Models	Phoenix	2
	Risk and Cost of Bad Data	Phoenix	2
	Cost-Effectiveness of Data Quality	McLean	2
	Determine the Costs and Benefits of Collecting Quality and Quantity of Data	Dallas	2
	Business Process Issues - Accountability	Phoenix	6
	How to Define the Success of the PMS	Phoenix	6
	Uncertainties and Reliability of Pavement Management Results	McLean	6
	Quality/Quantity of Pavement Management Data	Dallas	6
	Precision and Bias Statements for Pavement Testing Equipment	Dallas	1
Methods of Defining and Calculating the Effect of Pavement Preservation Treatments on Pavement Life	Determine Required Inputs and Expected Outcomes to Effectively Integrate Pavement Preservation Strategies into Pavement Management	Phoenix	9
	Guidelines for Distribution of Funding Among Various Strategies for Managing Pavements	Phoenix	6
	Cost, Benefit, and Risk of Integrating Pavement Preservation and Pavement Management	McLean	9
	Quantify and Communicate the Benefits of Preventive Maintenance on Pavement Performance	McLean	9
	Definition of Pavement Preservation Benefits	Dallas	9
	Models for Preventive Maintenance	Phoenix	4
	Better Understanding of Which Maintenance Activities Impact Pavement Performance	McLean	4
	Methods of Assessing Impact of Changes in Routine Maintenance	McLean	4
	Ways to Model Preventive Maintenance Activities	Dallas	4
	Identify Criteria Needed to Determine Treatments at the Network, Project, and Research Levels	Phoenix	5
	Incorporating Accurate and Complete Maintenance, Preservation, and Pavement Construction History	McLean	5
	Define Parameters Required for Integrating Pavement Preservation into Pavement Management	Dallas	5

Table 2. Final List of Research Needs Statements for Theme 2.

Theme 2: Institutional and Organizational Issues			
Short-Term Needs			
Title	**Contributing Problem Statement Title**	**Originating Regional Workshop**	**Originating Focus Area**
Annual Approval of SP&R Funding	Annual Approval of SP&R Funding	Phoenix	1
Addressing Trade-Offs, Metric Issues, and Purchasing Controls/Policies	Political and Organizational Issues/Inertia	Phoenix	3
Framework for Minimizing the Delivery of Treatment Applications	Improving the Contracting Process to Accommodate Timely Treatment Selection	McLean	5
Communicating Pavement Management Information and Benefits	Communication: Agency Staff Through Decision Makers	Phoenix	6
	Communicating With External Stakeholders	Phoenix	6
	Conveying and Communicating Output from Pavement Management	Phoenix	10
	Communicating the State of Pavements With Upper Management	McLean	6
	Communicating With the Public on the Cost of Pavement Infrastructure	McLean	6
	Best Practices for Reporting Strategic Pavement Needs to Management and Legislators	McLean	7
	Strategies for Effectively Marketing Pavement Management	McLean	10
	Selling Pavement Management to Politicians and Administrators	McLean	10
	Develop Communication Tools for Use With Agency Staff and Decision Makers on Treatment and Treatment Selection	Dallas	5
	Communicating (Internal and External) Issues and Solutions of Integrating Pavement Preservation and Pavement Management	Phoenix	9
	Quantify and Communicate the Benefits of Preventive Maintenance on Pavement Performance	McLean	9
	Develop Effective Leadership Support and Accountability	McLean	10
	Techniques for Gaining Buy-In from Decision Makers for Effective Pavement Management	McLean	10
	Selling Pavement Management to District (Field) Engineers	Dallas	10
	Use of Social Network Tools for Pavement Management Communications	Phoenix	7
Improving the Skills of Pavement Managers	Pavement Management Workforce Development	McLean	7
	Broaden Skills of Pavement Managers to be More Successful	McLean	10
	Institutionalizing Pavement Management through Workforce Development	McLean	10
	Maintaining Pavement Management Staffing and Skills for Proper Decision Making	Dallas	6

Table 2. Final List of Research Needs Statements for Theme 2 (Continued).

Theme 2: Institutional and Organizational Issues			
Short-Term Needs			
Title	**Contributing Problem Statement Title**	**Originating Regional Workshop**	**Originating Focus Area**
Improving the Skills of Pavement Managers	Pavement Management Training	Dallas	7
	Staffing and Succession Planning – FHWA Support for Education	Dallas	10
	Development and Delivery of Training for Data Collection	McLean	2
	Training and Curriculum for Pavement Data Quality	Dallas	2
	Continuous Education of Workforce on the Evolution of Pavement Management Data	Phoenix	3
	Cross Agency Institutional Issues in Data Management	Dallas	3
	Training Guide Outlining Pavement Management Fundamentals	Phoenix	4
	Pavement Management Academy	Phoenix	4
	Information on Where Maintenance is Applied and What Was Done	McLean	4
	Training Locals on Pavement Management Through LTAP	McLean	4
	Training on How to Do Modeling for Practitioners	Dallas	4
	Decisions Aligned with Data	Dallas	4
	Best Practices to Capture Construction, Preservation, and Maintenance Treatments	McLean	5
	Develop Effective Feedback from Pavement Preservation and Rehabilitation into the Pavement Management Database	Dallas	5
	Integrate Pavement Preservation into Pavement Management	Dallas	5
	Develop an Agency-Specific Pavement Management Process Manual	Dallas	2
	Need Attractive Career Path for Pavement Management Practitioners	Dallas	4
Long-Term Needs			
Title	**Contributing Problem Statement Title**	**Originating Regional Workshop**	**Originating Focus Area**
Identify IT Needs to Effectively Manage a Pavement Management System	Challenges Associated with Centrally Managed IT Environments	Dallas	3
Methods to Promote Pavement Management as a Management Tool	Effective Communication Toolset for Pavement Managers	Phoenix	8
	National Promotional Clip Promoting Pavement Management	Phoenix	8
	Conveying and Communicating Output from Pavement Management	Phoenix	10
	Promotion of Pavement Management Benefits to Non-Technical Audiences (Executives and Legislators)	McLean	8
	Strategies for Effectively Marketing Pavement Management	McLean	10

Table 2. Final List of Research Needs Statements for Theme 2 (Continued).

Theme 2: Institutional and Organizational Issues			
Long-Term Needs			
Title	**Contributing Problem Statement Title**	**Originating Regional Workshop**	**Originating Focus Area**
Methods to Promote Pavement Management as a Management Tool	Guidance on Understanding Benefits for Various Stakeholders, Including Defining Performance Measures and Goals	Dallas	8
	Develop Methods to Sell Pavement Management as a Management Tool	Dallas	8
	Selling Pavement Management to Politicians and Administrators	Dallas	10
Impact of Pavement Management Investment Levels on Benefits	Method to Quantify the Benefit of Information for Pavement Management	Phoenix	8
	Quantify Risks and Consequences of Changes in the Availability of Pavement Information	McLean	8
Suggested Topics for Pavement Management into the Civil Engineering Curriculum	Education of Future Practitioners in Pavement Management	McLean	8
Constant Funding for Pavement Management	Establish Need for Consistent Funding to Allow Appropriate Planning by Pavement Management Staff	Dallas	10
	Synthesis of Current Practices for Allocating Funding Resources While Dealing With Institutional Influences	McLean	9
	Quantifying the Effects of Sub-Optimal Decisions on Network Performance	McLean	9
Recommended Methodology to Calculate Pavement Asset Value and Communicate to Stakeholders	Recommended Methodology to Calculate Pavement Asset Value and Communicate to Stakeholders	Technical Panel Meeting	N/A

Table 3. Final List of Research Needs Statements for Theme 3.

Theme 3: The Broad Role of Pavement Management			
Short-Term Needs			
Title	**Contributing Problem Statement Title**	**Originating Regional Workshop**	**Originating Focus Area**
Pavement Management Data Mining: Improving Current Uses and Leveraging New Applications of Pavement Management Data	Input of Pavement Construction and Maintenance Data into Pavement Management	Dallas	2
	Data Integration Benefits	Phoenix	3
	Increasing Data Integration to Improve Stewardship	Phoenix	3
	Addressing Customer Service with Data Integration Systems	Phoenix	3
	Synthesis of Data Integration Systems	Phoenix	3
	Using Successful Pavement Management Practices to Frame and Guide Management System Development in Other Asset Areas	Dallas	3
	Addressing Near-Term Data Storage and Integration Technology Issues	Dallas	3
	Pavement Management Challenges and Practices Within Tolling Agencies	Dallas	3
	Pavement Management Data Mining: Improving Current Uses and Leveraging New Applications of Pavement Management Data	Phoenix	7
	Leveraging Pavement Management With Related Data Sources	McLean	7
	Merging of Data Sets Across Multiple Agencies Within a State	McLean	7
Modeling Load Limit Impacts	Modeling the Impacts of Load Limits on Pavement Performance	McLean	4
Use of Pavement Management Information for National Reporting	Develop National Performance Measures	McLean	4
	Pavement Management Data as Compared and Contrasted and Used Against Item Data	Phoenix	7
	Annual State of the Practice Report to FHWA	McLean	8
	Justification for Using Pavement Management Data in Lieu of HPMS for Reporting to FHWA	Dallas	7
	Expanding Treatment Selection Accountability in the Future	McLean	5
Development and Use of Effective Performance Measures	Goal Setting for Effective Pavement Management	Phoenix	6
	Synthesis on Consistent Terminology, Performance Targets, Measures, and Threshold Triggers	McLean	6
	Correlation Between Pavement Management Inputs and Performance Measures Reported	McLean	6
	Managing Pavements as an Investment	McLean	7
	Keeping Pavement Management Relative to the Asset Management Process	McLean	7
	Pavement Management as a Part of Asset Management	Dallas	6
	Measures Needed in Pavement Management to Support Pavement Preservation and Definition of Pavement Preservation Benefits	Dallas	9
	Develop Guidance on Use of Performance Measures in Decision Making	Dallas	9

Table 3. Final List of Research Needs Statements for Theme 3. (Continued).

Theme 3: The Broad Role of Pavement Management			
Short-Term Needs			
Title	**Contributing Problem Statement Title**	**Originating Regional Workshop**	**Originating Focus Area**
Development and Use of Effective Performance Measures	Goals and Performance Targets Related to Pavements	Phoenix	10
	Effect of Asset Management on Pavement Management	Phoenix	10
	Establishing a Performance Reporting System for Pavement Management Data	Dallas	10
Developing and Supporting a Pavement Management Business Plan	Developing and Supporting a Pavement Management Business Plan	Technical Panel Meeting	N/A
Long-Term Needs			
Title	**Contributing Problem Statement Title**	**Originating Regional Workshop**	**Originating Focus Area**
Using Pavement Management Data to Support Design Activities	Stronger Relationship Between Design and Pavement Management Models	McLean	4
	Best Practices for Incorporating the MEPDG into Pavement Management	McLean	7
	Feedback to Pavement Design	Dallas	7
	Advancing Analytical Tools for Continual Prediction Calibration	Dallas	7
Methodologies to Reliably Support Innovative Contracting	Use of Pavement Management in Performance-Based Warranty Contracts and Public-Private Partnerships	Phoenix	7
	Preparing Pavement Management to Reliably Support Innovative Contracting Processes	McLean	7
	Impact of Innovative Contracting Practices on Pavement Management	McLean	7
Identify Data Needs to Support Other Processes	Baseline Inventory of Network Needed for Decisions and Managing Pavements	Phoenix	2
	Pavement Management Data Integration to Support Future Transportation Needs	Phoenix	3
	Guidelines and Data to Support Transportation Asset Management Systems	McLean	3
National Funding Allocations That Account for State Priorities	Identifying How Individual State Priorities Hinder Development of National Standards	Phoenix	10
Impacts of Earmarks on Pavement Performance	Impacts of Earmarks on Long Range Plans and Pavement Conditions	Phoenix	10

Table 4. Final List of Research Needs Statements for Theme 4.

Theme 4: New Tools, Methodologies, and Technology			
Short-Term Needs			
Title	**Contributing Problem Statement Title**	**Originating Regional Workshop**	**Originating Focus Area**
Development of Automated Condition Data Processing Tools	Develop a Fully Automated Distress Identification	Phoenix	1
	Evaluation of Latest Technologies for Implementation in Pavement Management	Dallas	1
	Software Needs for Fully Automated Data Processing	Dallas	7
Analysis of Trade-Offs Associated with Alternate Methods of Data Collection	Analysis of Trade-Offs Associated with Alternate Methods of Data Collection	Technical Panel Meeting	N/A
Improving Factors Considered in Project and Treatment Selection Decisions	Strengthen Treatment Selection Through Workforce Development by Associating Condition Triggers with Improved Pavement Performance	McLean	5
	Using LCCA to Quantify Treatment Selections	McLean	5
	Develop Criteria, Create Manual and Training for Treatment Selection	Dallas	5
	Linkage of Pavement Management to Other Programs (e.g., Safety, Congestion, and Environment)	Phoenix	6
	Pavement Management Enhancements to Address Emerging Issues	McLean	6
	Incorporating User Costs in the Pavement Management Process	McLean	6
	Project Treatment Selection	Dallas	6
	Decision Support for Pavement Management	Dallas	7
	Identification of Non-Traditional Benefits for Inclusion in Optimization Analysis	McLean	5
	Characterizing Effective and Realistic Optimization Techniques for Implementable Pavement Treatment Solutions	McLean	5
Methods to Quantify the Benefits of Pavement Management	How Do We Address the Broad Reach of Pavement Management?	Phoenix	8
	Quantifying Pavement Management Benefits Related to User Costs	Phoenix	8
	Quantify the Benefits Derived from Pavement Management	Phoenix	10
	Synthesis of Current Methods for Quantifying Benefits	McLean	8
	Methods of Capturing Pavement Management Impacts on Other Programs and Identifying Societal Benefits (e.g., Economic and Environmental)	McLean	8
	Using Pavement Management to Support the Bottom Line in Private, Public/Private Transportation Asset Management Agencies	Dallas	8
	Methods to Quantify Benefits of Pavement Management Systems	Dallas	8
	Develop Guidance in Using Pavement Management to Justify and Defend Engineering Decisions	Dallas	8
	Links Between Infrastructure Health measures and Other Performance Measures	McLean	4

Table 4. Final List of Research Needs Statements for Theme 4. (Continued).

Theme 4: New Tools, Methodologies, and Technology			
Short-Term Needs			
Title	**Contributing Problem Statement Title**	**Originating Regional Workshop**	**Originating Focus Area**
Pavement Management in a Changing World	Effectively Managing Pavements in Changing Environments	McLean	10
	Future Trends Influencing Enhancements for Pavement Management Systems	Dallas	10
	Impact of Increased Data Requirements on Pavement Management (e.g., HPMS, MEPDG, and HERS-ST)	Dallas	10
Long-Term Needs			
Title	**Contributing Problem Statement Title**	**Originating Regional Workshop**	**Originating Focus Area**
Automation of Surface Texture Characteristics	New Applications for Use of Macrotexture	Phoenix	1
	Automation of Surface Texture Characteristics	Dallas	1
	Identification of Non-Traditional Factors Impacting Pavement Deterioration	Dallas	4
	Develop Additional Pavement Condition Measures in the Decision Making Process for Proper Treatment Selection	McLean	5
Method for Effectively Modeling Structural Condition	Models to Capture Both Functional and Structural Components	Phoenix	4
	Methods of Modeling Structural Adequacy	McLean	4
	Methods of Effectively Modeling Structural Condition	Dallas	4
	Quantification of Network Level Structural Condition Using High-Speed Deflection Testing	McLean	1
	Quantifying the Benefits of Structural Capacity Testing	Dallas	1
	Optimizing the Efficiency of Deflection Testing	Dallas	1
	Automation of Material Properties Characterization	Dallas	1
Impact of Climate Change on Performance Prediction	Impact of Climate Change and Sustainability Efforts on Models	Phoenix	4
Develop Default Models for Low-Volume Roads	Nationally Developed Default Models for Low-Volume Roads for Pavement Management and MEPDG	McLean	4
Performance Models That Consider Series of Treatments	Performance Models That Consider a Series of Treatments	Technical Panel Meeting	N/A
Quantifying the Benefits of Pavement Research	Market Analysis of Pavement Research Benefits	McLean	7
Quantifying the Cost of Pavement Use	Quantifying the Cost of Pavement Use	McLean	7
Identifying Strategies for Incorporating Emerging Technologies into the Pavement Management System	Sustainability in Changing Needs and Emerging Technology in Data Collection and Analysis	Phoenix	7
	Clearinghouse for Evaluation of New Technologies	Phoenix	7
	Optimizing Pavement Surface Properties	McLean	7
	Development of Methodologies and Analysis Tools to Incorporate Sustainability	McLean	7

Table 4. Final List of Research Needs Statements for Theme 4. (Continued).

Theme 4: New Tools, Methodologies, and Technology			
Long-Term Needs			
Title	**Contributing Problem Statement Title**	**Originating Regional Workshop**	**Originating Focus Area**
Identifying Strategies for Incorporating Emerging Technologies into the Pavement Management System	Emerging Technologies in Electronic Data Collection	McLean	7
	Identification and Validation of Emerging Hardware Technologies	Dallas	7
	Identify Emerging Technologies That Drive Pavement Management Needs	Dallas	7
Develop Nondestructive Testing (NDT) for Measurement of In-Place Material Properties	Develop Technology and Equipment That Can Measure In-Place HMA Density, Full Width (NDT)	Phoenix	1
Use of Aerial Images for Distress Analysis	Use of Aerial Images for Distress Analysis	Phoenix	1
	Use or Appropriate Application of New Technologies for Data Collection	Phoenix	2
Development and Integration of Wireless Sensors With Pavement Management	Development and Integration of Wireless Sensors With Pavement Management	Technical Panel Meeting	N/A

Prioritizing the Combined List of Needs

The attendees from the three regional workshops were invited to participate in a webconference at which the combined list of needs was presented. Immediately following the webconference, participants were given an opportunity to vote on the relative importance of each of the needs statements and their perceived priorities within each theme. As part of this activity, participants were asked to assign a relative importance to each needs statement, using the following terms:

- Very Important.
- Important.
- Not Very Important.

In addition, participants were asked to rank the needs statements within each of the theme areas, on a scale of 1 to 5, with 1 being the high priority. To facilitate the ranking, short-term and long-term needs within each theme were ranked separately. As a result, each participant provided a total of eight ranked lists (four theme areas multiplied by two lists for short-term and long-term needs). A computerized balloting tool was used to facilitate this activity and a total of fifty-three individuals participated in the ranking exercise.

The results of the balloting were used to develop the prioritized list of short-term and long-term needs included in the next chapter. For use in the ranking process the relative importance levels were assigned the following values: very important = 3 points, important = 2 points, and not very important = 1 point. The priorities were established by multiplying the average relative importance and the average ranking assigned by the participants for each needs statement. The results produced, in essence, a weighted average that could be used to develop a ranked list that combines the results from each theme, regardless of the number of needs statements within the theme.

3.0 A 10-Year Roadmap for Pavement Management

The Vision for Pavement Management

The successful adoption of the Pavement Management Roadmap is expected to lead to the increased use, and improved applicability, of pavement management by eliminating the barriers or gaps that limit its effectiveness or hinder its acceptance within an agency. Through comprehensive and coordinated efforts to address both the short-term (i.e., less than 5 years) and long-term (i.e., 5 to 10 years) research, development, technology, and workforce development activities identified in this Roadmap, practitioners can foresee the following vision of pavement management in the year 2020.

The Vision for Pavement Management in 2020

Pavement management will make use of a new generation of technology so agencies are less dependent on manual labor for data collection. Pavement management tools will allow agencies to communicate effectively with stakeholders, using clear statements that are tied to agency goals and pavement worth. Within an asset management framework, pavement management will be used for investigating decisions and program options in both private and public sectors. A pavement management analysis will consider new materials and construction/design practices, as well as other factors that influence project and treatment selection, including safety, congestion, and sustainability. As a result of these changes, pavement management will be robust, comprehensive, and credible, and will address agency needs at the project, network, and strategic levels.

Prioritized Research, Development, and Technology Transfer Needs

The final research, development, and technology transfer needs within each theme are provided in Appendix B of this report. The comprehensive needs statements are presented in a format that can easily be used by any agency to secure the funding needed to advance any of the initiatives. The Pavement Management Roadmap presented in this section of the report prioritizes the urgency with which these activities should be addressed, based on the importance and priority rankings provided by the participants. As such, the prioritized list of short-term and long-term needs represents the urgency with which the participating pavement management stakeholders would address these activities. The results are presented in a number of different formats to emphasize the priorities across theme areas, as well as within theme areas.

In total, the suggested initiatives represent over $14.5 million in funding, with approximately $6.5 million representing short-term needs over the next 5 years and $8 million representing long-term needs to be initiated within the next 5 to 10 years. By theme area, the funding is distributed in accordance with the figures shown in table 5.

Table 6 and 7 present the prioritized listing of recommended needs to address the gaps in pavement management over the next 10 years, ignoring the four theme areas. Table 6 presents the prioritized listing of the short-term needs, and table 7 includes the prioritized listing of long-term needs.

Table 5. Funding Needs by Theme Area.

Theme	Short-Term Needs (< 5 years)		Long-Term Needs (5 to 10 years)		Totals	
	# of Projects	Funding Requirements	# of Projects	Funding Requirements	# of Projects	Funding Requirements
1: Use of Existing Technology and Tools	8	$2,180,000	2	$850,000	10	$3,030,000
2: Institutional and Organizational Issues	5	$880,000	6	$780,000	11	$1,660,000
3: The Broad Role of Pavement Management	5	$1,550,000	5	$1,300,000	10	$2,850,000
4: New Tools, Methodologies, and Technologies	5	$1,930,000	11	$5,100,000	16	$7,030,000
Totals	***23***	***$6,540,000***	***24***	***$8,030,000***	***47***	***$14,570,000***

Table 6. Prioritized Listing of Short-Term Needs.

Priority Ranking	Title	Theme	Score
1	Communicating Pavement Management Information and Benefits	Inst & Org	2.18
2	Development and Use of Effective Performance Measures	Broad Role	2.16
3	Improving the Skills of Pavement Managers	Inst & Org	2.13
4	Development of Automated Condition Data Processing Tools	New Tools	1.85
5	Methods to Quantify the Benefits of Pavement Management	New Tools	1.85
6	Best Practices for Pavement Management	Existing Tools	1.65
7	Development of Pavement Distress Standards	Existing Tools	1.62
8	Development of Improved Methodologies for Evaluating Data Quality	Existing Tools	1.58
9	Improving Factors Considered in Project and Treatment Selection Decisions	New Tools	1.58
10	Establish and Develop Equipment Calibration Centers and Guidelines	Existing Tools	1.55
11	Comprehensive Study to Guide the Integration of Pavement Preservation and Pavement Management	Existing Tools	1.44
12	Pavement Management Data Mining: Improving Current Uses and Leveraging New Applications of Pavement Management Data	Broad Role	1.37
13	Analysis of Trade-Offs Associated with Alternate Methods of Data Collection	New Tools	1.33
14	Load Limit Impacts on Pavement Performance	Broad Role	1.19
15	Developing and Supporting a Pavement Management Business Plan	Broad Role	1.18
16	Use of Pavement Management Information for National Reporting	Broad Role	1.07
17	Annual Approval of SP&R Funding	Inst & Org	0.89
18	Framework for Minimizing the Delivery of Treatment Application	Inst & Org	0.89
19	Independent Technical Assessments of Pavement Management	Existing Tools	0.84
20	Pavement Management Clearinghouse	Existing Tools	0.80
21	Addressing Trade-offs, Metric Issues, and Purchasing Controls/Policies	Inst & Org	0.62
22	Synthesis of External Issues Driving Pavement Management	Existing Tools	0.60
23	Pavement Management in a Changing World	New Tools	0.49

Table 7. Prioritized Listing of Long-Term Needs.

Priority Ranking	Title	Theme	Score
1	Methods of Defining and Calculating the Effect of Pavement Preservation Treatments on Pavement Life	Existing Tools	2.43
2	Impact of Pavement Management Investment Levels on Benefits	Inst & Org	2.26
3	Using Pavement Management Data to Support Design Activities	Broad Role	2.08
4	Performance Models that Consider Series of Treatments	New Tools	1.97
5	Method for Effectively Modeling Structural Condition	New Tools	1.91
6	Methods to Promote Pavement Management as a Management Tool	Inst & Org	1.82
7	Investigation into the Risk, Uncertainty, and Variability in Pavement Management Decisions	Existing Tools	1.45
8	Automation of Surface Texture Characteristics	New Tools	1.40
9	National Funding Allocations That Account for State Priorities	Broad Role	1.33
10	Identifying Strategies for Incorporating Emerging Technologies into the Pavement Management System	New Tools	1.23
11	Identify Data Needs to Support Other Processes	Broad Role	1.20
12	Quantifying the Cost of Pavement Use	New Tools	1.19
13	Recommended Methodology to Calculate Pavement Asset Value and Communicate to Stakeholders	Inst & Org	1.16
14	Methodologies to Reliably Support Innovative Contracting	Broad Role	1.13
15	Develop NDT for Measurement of In-Place Material Properties	New Tools	1.08
16	Suggested Topics for Pavement Management Into the Civil Engineering Curriculum	Inst & Org	1.03
17	Constant Funding for Pavement Management	Inst & Org	0.96
18	Identify IT Needs to Effectively Manage a Pavement Management System	Inst & Org	0.95
19	Quantifying the Benefits of Pavement Research	New Tools	0.78
20	Impact of Earmarks on Pavement Performance	Broad Role	0.70
21	Develop Default Models for Low-Volume Roads	New Tools	0.47
22	Impact of Climate Change on Performance Prediction	New Tools	0.39
23	Development and Integration of Wireless Sensors with PMS	New Tools	0.36
24	Use of Aerial Images for Distress Analysis	New Tools	0.29

Recommended Short-Term Needs by Theme Area

The regional workshops produced a total of twenty-three short-term research, development, and technology transfer needs to be addressed within the next 5 years to advance pavement management capabilities. To a significant degree, the problem statements emphasize the need for improved access to information about best practices, and better methods to communicate the importance of pavement management to transportation agencies. Additionally, stakeholders placed an emphasis on improving data quality and consistency. The top ten short-term research, development, and technology transfer needs are presented in this section of the report, by theme area. The entire set of problem statements for all needs can be found in Appendix B.

Theme 1: Use of Existing Technology and Tools

Needs statements included in theme 1 include recommendations for technology and tools that can support traditional pavement management applications. In general, this theme includes technology

and tools that are currently available today but are in need of additional review, analysis, dissemination, and/or updating prior to their use.

The needs from this theme that are featured in the top ten list of short-term needs are provided in table 8. A total of $2,180,000 in funding is required to address these needs.

Theme 2: Institutional and Organizational Issues

The theme 2 needs statements relate to workforce development, communication, contracting, and organizational structure. The recommendations in this area are intended to address issues that include the impact pavement management on funding and how to determine, promote, and effectively communicate the use and the benefits of pavement management.

The needs from this theme that are featured in the top ten list of short-term needs are provided in table 8. A total of $880,000 in funding is required to address these needs.

Theme 3: The Broad Role of Pavement Management

Theme 3 includes needs statements that go beyond the standard functions of pavement management and include such areas as pavement design, impact of increasing load limits on pavement performance, and asset management.

The needs from this theme that are featured in the top ten list of short-term needs are provided in table 8. A total of $1,550,000 in funding is required to address these needs.

Theme 4: New Tools, Methodologies, and Technologies

The problem statements in theme 4 are related to needs for research and development leading to new tools, methods, and technology to support pavement management. In general, needs statements included in this theme address concepts that are not readily available and will require a higher level of research, analysis, and development prior to implementation.

The needs from this theme that are featured in the top ten list of short-term needs are provided in table 8. A total of $1,930,000 in funding is required to address these needs.

Table 8. Top 10 Listing of Short-Term Needs Statements by Theme.

Needs Statement	Description	Funding
Theme 1: Use of Existing Technology and Tools		
Needs Statement	**Description**	**Funding**
Best Practices for Pavement Management	There is a significant need to assemble and prepare a best practices document for the operational and functional aspects of pavement management. This guide will include a broad range of topics, such as benefits and limitations of data collection equipment and procedures, processes for developing and implementing a linear referencing system and addressing data integration issues, guidelines for developing and updating performance modeling, methods for using pavement management to support agency decisions and allocated funds, and methods for communicating pavement management data to stakeholders.	$500,000
Development of Pavement Distress Standards	This study will identify distress to be measured, review current state practice, compare state procedures to current AASHTO protocols, identify areas not currently covered by an AASHTO protocol, develop preliminary protocols, conduct webinars or workshops to obtain state buy-in, and finalize the protocol for AASHTO balloting.	$350,000
Development of Improved Methodologies for Evaluating Data Quality	This study's objective is to develop a standard methodology that can be applied to a wide range of pavement condition data to assess quality in terms of accuracy and repeatability. The study results will establish data collection guidelines and evaluate the impact of variability. A product will be the development of guidelines to improve data quality in terms of collection, processing, and reporting.	$350,000
Establish and Develop Equipment Calibration Centers and Guidelines	This study will identify potential calibration sites, recommended calibration frequencies, and calibration procedures.	$250,000
Theme 2: Institutional and Organizational Issues		
Needs Statement	**Description**	**Funding**
Communicating Pavement Management Information and Benefits	This study will investigate how highway agencies have successfully gained buy-in from decision makers that have led to increased use of pavement management information. The products will include guidelines for making these types of presentations, and a collection of effective presentations that can be used as templates.	$250,000
Improving the Skills of Pavement Managers	This initiative will provide guidance to help agencies evaluate the economic/organizational impacts of workforce development. This study will develop training guides, a web clearinghouse for resources, and information on pavement management careers.	$250,000
Theme 3: The Broad Role of Pavement Management		
Needs Statement	**Description**	**Funding**
Development and Use of Effective Performance Measures	Under this study, examples of effective links between strategic and operational performance measures will be conducted, and guidelines on the use of pavement management measures to support strategic initiatives will be developed.	$250,000
Theme 4: New Tools, Methodologies, and Technologies		
Needs Statement	**Description**	**Funding**
Development of Automated Condition Data Processing Tools	Improvements to current tools for automating the processing of some measures of pavement evaluation are needed to accelerate the rate which survey results become available and improve the consistency and reliability of the information. Improvements are needed to the processing of surface distress data, GPR, and rutting.	$800,000
Methods to Quantify the Benefits of Pavement Management	This is a synthesis study in which practices in public and private agencies may be explored to determine current practice. The end product is the identification of effective methodologies that can be used to quantify benefits associated with pavement management.	$30,000
Improving Factors Considered in Project and Treatment Selection Decisions	The study must provide guidance for addressing agency challenges that influence the use of this information. The product of this research will be a process for evaluating the decision factors used in the pavement management treatment selection process and guidelines for addressing any existing gaps in the criterion.	$250,000

Other identified short-term needs not included in the top ten listing include the following:

- **Theme 1: Use of Existing Technology and Tools**
  - — Comprehensive Study to Guide the Integration of Pavement Preservation and Pavement Management. In most agencies, pavement management data collection and analysis tools were established before pavement preservation techniques were used extensively. As a result, the data that are currently collected and the project selection processes are not necessarily easily modified to include preventive maintenance treatments. Therefore, this study will provide guidelines for adapting pavement management systems to fully support pavement preservation activities at the state and local levels. First, the researchers will conduct a synthesis of best practice, to determine how agencies have approached the integration of preventive maintenance treatments into pavement management. Based on that information, pavement preservation definitions will be developed that reflect activities associated with the management of pavement assets over their entire life cycle. The study will investigate the data needed to support the integration of preventive maintenance into pavement management and will identify various levels of integration (including the costs, benefits, and risks associated with each). The final product will provide guidance on how agencies can integrate their pavement preservation and pavement management practices at each of the levels identified.
  - — Independent Technical Assessments of Pavement Management. The FHWA is a strong supporter of pavement management tools in state highway agencies, but the use of these tools is optional. Further, there are diverse approaches being used for data collection, reporting, and analysis within these agencies. There is also a lack of established appraisal methods for determining whether pavement management practices comply with "good practice." At the same time, agencies are facing funding constraints that limit the resources available to support pavement management. This study will support pavement management by establishing baseline capabilities for pavement management and conducting independent assessments within each of the state highway agencies to determine a) whether the baseline capabilities are met and b) how any deficiencies can be addressed. The study would be strengthened if funding were provided to agencies to help them address the existing deficiencies.
  - — Pavement Management Clearinghouse. Technology advances in pavement distress data collection are often difficult to for an agency to monitor, evaluate, and determine implementation appropriateness. In addition, there are many resources that are of value to pavement management practitioners, but a great deal of time can be spent trying to locate the information. It would also be beneficial for transportation agencies to have a readily available list of local, regional, and national contractors and their capability of constructing the vast array of pavement preservation and rehabilitation treatments. In this manner, an agency looking to apply a specific treatment (e.g., microsurfacing, hot in-place recycling) can access a web-based clearinghouse to determine contractor capabilities. A centralized repository of equipment availability, technology advancements, resources, and contractor availability and capability is necessary. This study will develop requirements for establishing a pavement management clearinghouse, design and develop a website for housing the clearinghouse, and provide future website maintenance and updates.
  - — Synthesis of External Issues Driving Pavement Management. There are many factors that impact pavement management that are beyond the control of agency staff or administrators. With changes in available funds for transportation, agencies have to adapt to new approaches for funding, contracting, and/or project acceptance. These external forces have undoubtedly

influenced pavement management needs and priorities. This synthesis will investigate the factors that have impacted pavement management recently and document the ways that pavement managers have responded to these demands.

- **Theme 2: Institutional and Organizational Issues**
  - — Annual Approval of SP&R Funding. The annual approval of SP&R funding does not currently match the timing of data collection and processing for most state highway agencies. When SP&R funds are available for use, they expire at the end of the year making difficult for the state highway agency to expend the approved funds. This study will identify the SP&R funding restrictions, identify solutions that will meet FWHA and state highway agency requirements, determine recommended solutions, and suggest policy changes.
  - — Framework for Minimizing the Delivery of Treatment Applications. Often time's pavement rehabilitation/preservation projects are delayed due to plan preparation, advertising, and letting. This lag time between project selection and construction may render the selected treatment ineffective due to the advancement of pavement distress. There is a need to develop a process for reducing the timing between project selection and treatment application to ensure proper treatment application. This study will develop a framework for minimizing the lag time between project development and construction initiation.
  - — Addressing Trade-offs, Metric Issues, and Purchasing Controls/Policies. Political, organizational issues, and organizational inertia frequently impede the pavement management process and the implementation of beneficial information for all entities. Key issues for these entities fit in the areas of trade-offs, metric terms/issues, policies, and purchasing controls. This study will survey state highway agencies to determine how new technology has been implemented and political and organization issues have been overcome.
- **Theme 3: The Broad Role of Pavement Management**
  - — Pavement Management Data Mining: Improving Current Uses and Leveraging New Applications of Pavement Management Data. There is an untapped potential to make greater use of pavement management data to better address current agency needs and to provide insight into new areas (e.g. asset value, new design methods, improved construction practices, corridor studies, and impacts of weight limits on performance). However, for these types of analyses to take place, it is important that data from related data sources are better leveraged. This study will explore the issues associated with better leveraging of pavement management data and provide guidelines for overcoming these issues. Examples from case studies that illustrate new potential uses of pavement management data will be provided.
  - — Load Limit Impacts on Pavement Performance. States are faced with requests for load exemptions and often grant or deny these requests without a full understanding of the overall impact of pavement performance. The national government is also pressured to raise the current 80,000 lb legal load limit to 97,000 lbs on interstate roadways. What is needed is an easy to use (and understand) analysis tool that will estimate the impacts due to increased axle loading. This tool would determine the best measure (e.g., IRI, percent cracking, rutting) for assessing the incremental impact, assess the impact over an entire pavement network, corridor, or specific roadway segment, and estimate the financial impact due to increased damage (i.e., added costs for preservation and rehabilitation treatments to maintain the roadway, corridor, or network).

— Developing and Supporting a Pavement Management Business Plan. Pavement Management has been around for decades, but in some ways the integration of pavement management into the core business function of many agencies is very immature. Defining the focus for pavement management and defining and developing necessary skills should be documented in the form of a pavement management business plan. The term pavement management means very different things to different people. This research will define core business functions of pavement management, skills needed to support these core functions, ways to help practitioners develop those skills, strategies to push pavement management to be more prevalent in agency functions, and determine appropriate ways to address and manage the myriad of tangential functions that pull at pavement management.

— Use of Pavement Management Information for National Reporting. In many states, HPMS data and pavement management data are collected by separate divisions or reported out by someone not involved in the data collection process. In some cases, the HPMS data are "passed off" without regard for the accuracy of reporting the information. As a result, there can be issues with data quality between what is collected by pavement management and what is reported to FHWA through the HPMS process. Additionally, there is an inefficient use of resources if similar data are being collected by two different groups within the same agency. There is also generally less buy-in or credibility in the HPMS data than in the pavement management data. Further, HPMS data does not always represent data that drives an agency's project and treatment selection process. During this study, an investigation will be conducted to determine the information needed at a national level to report pavement conditions to Congress. The results will be compared to available HPMS and pavement management data to determine strategies for using more pavement management data for national reporting and to lessen the reliance on separate HPMS data. A final product will be guidelines for a standardized method of reporting this information.

- **Theme 4: New Tools, Methodologies, and Technologies**

— Analysis of Trade-Offs Associated with Alternate Methods of Data Collection. As new technology comes along to aid in the pavement management efforts, many agencies will be contemplating whether they should switch from their current practices and adopt these new ones. Due, in part, to limited budgets, but also as a practical matter, agencies will need to determine which of their current activities can be modified or even eliminated as a result of this new technology. This project would develop a procedure that agencies can follow to determine the trade-offs and weigh the benefits of switching to a new technology. This study will review what data is currently being collected, identify equipment and analysis procedures that are being used, and what, little used new technology might be available for a state agency to consider. In addition, develop a tool to show the trade-offs of one versus the other capturing the pros/cons, added costs or savings, etc. so that there can be a clear discovery of the impact this change would have on the agency's budget, labor force, analysis schedule, etc. Case studies will be conducted to show the results of this study.

— Pavement Management in a Changing World. Pavement management must operate in an environment that is constantly changing. For instance, there are continual changes in leadership and each change typically brings new agendas. There are also unfunded mandates, changes in freight weights and movements, increased data requirements, scope creep, and changes in regulations that must be addressed. Transportation agencies have limited experience communicating the impacts of these changes on the highway network. This study will result in the development of metrics that help agencies identify what aspects can be

addressed by pavement management and what aspects cannot be represented in a pavement management analysis.

Recommended Long-Term Needs by Theme Area

The regional workshops produced a total of twenty-four long-term research, development, and technology transfer needs to be addressed within the next 5 to 10 years to advance pavement management capabilities. As opposed to the short-term needs, this list includes activities that will require research to develop methods to improve existing practices. The highest ranked needs indicate that efforts are needed to define and calculate the impact of pavement preservation treatments, and to determine the impact of different investment levels on pavement management capabilities. Additional efforts address the need to better support pavement design activities with pavement management, including the need to effectively model structural condition and series of treatments over a pavement life cycle. The top ten long-term research, development, and technology transfer needs are described in this section of the report, by theme area. The entire set of problem statements for all of the needs identified, can be found in Appendix B.

Theme 1: Use of Existing Technology and Tools

Need statements included in theme 1 include recommendations for technology and tools that can support traditional pavement management applications. In general, this theme includes technology and tools that are currently available today, but are in need of additional review, analysis, dissemination, and/or updating prior to their use.

The needs from this theme that are featured in the top ten list of long-term needs are provided in table 9. A total of $850,000 in funding is required to address these needs.

Theme 2: Institutional and Organizational Issues

The theme 2 needs statements presented in this section of the report relate to workforce development, communication, contracting, and organizational structure. The recommendations in this area are intended to address issues that include the impact pavement management on funding and how to determine, promote, and effectively communicate the use and the benefits of pavement management.

The needs from this theme that are featured in the top ten list of long-term needs are provided in table 9. A total of $780,000 in funding is required to address these needs.

Theme 3: The Broad Role of Pavement Management

Theme 3 includes needs statements that go beyond the standard functions of pavement management and include such areas as pavement design, impact of increasing load limits on pavement performance, and asset management.

The needs from this theme that are featured in the top ten list of long-term needs are provided in table 9. A total of $1,300,000 in funding is required to address these needs.

Theme 4: New Tools, Methodologies, and Technologies

The problem statements in theme 4 are related to needs for research and development leading to new tools, methods, and technology to support pavement management. In general, needs statements included in this theme address concepts that are not readily available and will require a higher level of research, analysis, and development prior to implementation.

The needs from this theme that are featured in the top ten list of long-term needs are provided in table 9. A total of $5,100,000 in funding is required to address these needs.

Table 9. Top 10 Listing of Long-term Needs Statements by Theme.

Needs Statement	Description	Funding
Theme 1: Use of Existing Technology and Tools		
Needs Statement	**Description**	**Funding**
Methods of Defining and Calculating the Effect of Pavement Preservation Treatments on Pavement Life	This study will quantify the impacts that pavement preservation treatments have on pavement performance, using measured field data from various geographic regions of the country.	$500,000
Investigation into the Risk, Uncertainty, and Variability in Pavement Management Decisions	The objective of this research is to investigate the various forms of variability affecting pavement management recommendations and to develop a process for evaluating its impact and the overall effectiveness of pavement management recommendations. The results are expected to be able to help agencies determine the amount of data needed to provide credible recommendations and to determine what level of risk is considered acceptable, thereby improving levels of accountability and confidence in pavement management.	$350,000
Theme 2: Institutional and Organizational Issues		
Needs Statement	**Description**	**Funding**
Impact of Pavement Management Investment Levels on Benefits	A product of this study is the development of an analysis approach that determines the relationship between funding expenditures, data reliability, and system outputs. Another product will be the development of a methodology for analyzing these relationships.	$350,000
Methods to Promote Pavement Management as a Management Tool	Pavement management's value to is not always well understood, especially among executives and elected officials with short-term positions. Public relations is needed to raise the profile of pavement management and communicate its wide-ranging benefits. Research is needed to know how to be most effective with audiences.	$100,000
Theme 3: The Broad Role of Pavement Management		
Needs Statement	**Description**	**Funding**
Using Pavement management Data to Support Design Activities	This study will develop a methodology to enhance the sophistication of pavement performance modeling, determine the availability of data fields for both pavement management and pavement design, determine the compatibility of MEPDG and pavement management prediction, enhance DARWin-ME or develop a stand-alone tool, and recommend adjustments to calibrate one or both models.	$350,000
National Funding Allocations That Account for State Priorities	This study will result in the development of a methodology for comparing pavement performance that accounts for the differences in state priorities and objectives.	$250,000
Theme 4: New Tools, Methodologies, and Technologies		
Needs Statement	**Description**	**Funding**
Performance Models That Consider a Series of Treatments	This study will include a literature search on the pavement performance impacts of a series of treatments; development of a strategy for evaluating treatments in a series; collection of sufficient data from state agencies to develop, analyze, and validate performance curves; and the creation of guidelines on how to develop performance curves for a series of treatments.	$500,000
Method for Effectively Modeling Structural Condition	This study will quantify the cost/benefit of network-level deflection testing. The researcher will conduct a survey of practice, validate testing with other static devices, determine precision and bias statements, conduct pilot studies, and develop guidelines.	$350,000
Automation of Surface Texture Characteristics	This study will identify surface characteristics that can be identified and quantified using existing high-speed data collection equipment; potential methodologies for quantifying distress; equipment and analysis gaps; and software and equipment modifications.	$500,000
Identifying Strategies for Incorporating Emerging Technologies into the Pavement Management System	The main research objective is to develop a framework for identifying/evaluating the changes that impact pavement management decisions. The framework should be applicable to a wide range of situations and be demonstrated using data provided by state highway agencies. The final product is a set of guidelines for identifying and evaluating factors that influence the recommendations produced by the pavement management system. A clearinghouse for reporting the evaluation of technology may also be a product.	$350,000

Other identified long-term needs not included in the top ten listing include the following:

- **Theme 2: Institutional and Organizational Issues**
  - — Recommended Methodology to Calculate Pavement Asset Value and Communicate to Stakeholders. Asset management systems have traditionally been required to answer the following fundamental questions: what assets do we have, where are they, and what condition are they in? A fourth but equally fundamental question now also exists: what is the value of our assets both today and expected over the life cycle? This study will conduct a literature review of asset valuation methodology for civil infrastructure and particularly on how it has been applied to pavements at the strategic, network, and project level; identify the positive features and the methodology shortcomings; review GASB 34 requirements and reporting procedures; and prepare recommendations for pavement asset valuation.
  - — Suggested Topics for Pavement Management Into the Civil Engineering Curriculum. There is not sufficient emphasis on pavement management in a civil engineering curriculum. As a result, there is a steep learning curve for new practitioners. Therefore, there is a need to raise the awareness of pavement management concepts in the existing college curriculums.
  - — Constant Funding for Pavement Management. Inconsistent levels of funding make it difficult for pavement management staff to keep pavement conditions at a consistent level and to predict future needs (preservation, rehabilitation, and reconstruction) of the system. Additionally, it is difficult to maintain a consistent level of work for designers and contractors. This study will conduct a synthesize of current approaches for allocating funding, summarize the advantages/disadvantages of each approach, quantify the impacts of suboptimal allocations, and identify the monetary needs for a consistent pavement management work program will be established to allow agencies to optimize pavement treatments and funding.
  - — Identify IT Needs to Effectively Manage a Pavement Management System. As agencies seek to achieve efficiencies in information technology practices, users of technologies are experiencing challenges for accessing, manipulating, and using technology associated with IT. This study will identify common goals of centrally management decision makers and identify needs and gaps between pavement management managers and centrally managed IT managers.
- **Theme 3: The Broad Role of Pavement Management**
  - — Identify Data Needs to Support Other Processes. As data collection has become more sophisticated, the demand on data contained within the pavement management system has increased. This has been noted by pavement performance data for use in calibration of the MEPDG, the HPMS reassessment, warranties, public-private partnerships, forensic studies, and so on. An assessment of what data is needed to support these various applications is needed. This study will identify applications that could benefit from pavement management data, identify current data that can be used to improve/enhance these applications, identify gaps in needed data, and provide guidelines on how to better utilize pavement management data in other applications.
  - — Methodologies to Reliably Support Innovative Contracting. With increases in the use of warranty, concessionary, and public-private-partnerships, and other innovative contracting processes, changes in the use of pavement management data can be expected. For instance, historical pavement performance data and forecasted conditions may be used to set acceptable condition levels and to determine whether contractual performance requirements have been

satisfied. As a result, a higher level of reliability is required of the data than is needed for traditional processes and so data collection processes may need to be modified. The focus of this research effort is to determine the changing needs on pavement management associated with innovative contracting and the development of recommendations for addressing these needs.

— Impact of Earmarks on Pavement Performance. Earmarks can use (consume) considerable SHA funding, leaving less funds to address the needs of the entire highway system. Some earmarks require bond indebtedness that has a long lasting obligation to the SHA. When earmarks are large in dollars or numbers, they significantly alter the ability of the SHA to address pressing needs such as pavement preservation. This study will investigate the impact that earmarks have had on pavement conditions in select states. The findings will be used to promote the reduction or elimination of earmarks and their impact on transportation funding.

- **Theme 4: New Tools, Methodologies, and Technologies**

— Quantifying the Cost of Pavement Use. It is likely that "pay per use" strategies for funding transportation projects will be used increasingly in the future. However, this requires agencies to quantify the cost of providing a sound, safe pavement for customer use so that rational pricing schemes can be developed. In addition, the research needs to investigate the pavement management data needed to support this type of initiatives. The research will result in the development of an economic framework to derive the pricing scheme and guidelines on its use.

— Develop NDT for Measurement of In-Place Material Properties. Areas of low density in HMA pavements are susceptible to early failure due to stripping, cracking, and potholes. Low strength in PCC pavements can result in fatigue cracking, poor load transfer, and spalling. The ability to quantify full-width material properties, such as HMA density and PCC strength, would be beneficial for determining contractor pay incentives, quality assurance, and performance prediction models. Research using ground penetrating radar (GPR) to determine HMA density has been conducted; however, this process has not received wide-spread use in the United States. Similarly for PCC, the use of impact echo and spectral analysis of surface waves have been evaluated and utilized, but have not received wide-spread use. This study will review current research, identify limitations/benefits of testing equipment and procedures, and identify the most effective and accurate methodology for determining in-place material properties, full-width, at highway speed.

— Quantifying the Benefits of Pavement Research. Several industries, such as the pharmaceutical industry, regularly invest a percent of their sales in research and development activities. This practice is not widely practices in the transportation agency; therefore, the consequences associated with the lack of funded research are not well understood. Under this research effort, a method of evaluating the investment made in research will be developed and demonstrated. The results of this effort are expected to lead to increased innovation in pavement management.

— Develop Default Models for Low-Volume Roads. Many pavement management systems were not developed using data from low-volume roadways. The MEPDG, due to lack of data, specifically excluded low-volume roadways. Pavement performance and treatment selection on low-volume roadways can be significantly different than that of higher volume roadways. This research will investigate the availability of data (e.g., performance, construction, and traffic) on low-volume roadways, will modify/develop performance prediction equations,

develop pavement design procedures/practices, and develop guidelines for incorporating low-volume roadways into pavement management systems and pavement design practices (specifically, DARWin-ME).

— Impact of Climate Change on Performance Prediction. Little is known about the impact of climate change (e.g., temperature rise, sea level rise, and increased storm frequency) on the future performance of highway pavements. This study will investigate pavement performance on roadway networks subjected to the effects of climate change, evaluating existing models on predicting changes in pavement performance, and develop/revise models as necessary to reflect these impacts.

— Development and Integration of Wireless Sensors with Pavement Management. There is on-going research to develop a self-contained smart pavement monitoring system consisting of wireless integrated circuit sensors. The envisioned system would consist of a network of low cost sensors distributed along the pavement during new/reconstruction or resurfacing. Each sensor node would be self-powered and capable of continuously monitoring and storing the dynamic strain levels in host pavement structure. The data from all the sensors would be periodically uploaded wirelessly to a central database. The data will help facilitate a more effective pavement maintenance and rehabilitation/preservation schedule. Additional research is needed to optimize data collection and storage with these types of sensors. Efforts are needed to integrate this sort of data within existing agency databases in order to make optimal use of the data available.

— Use of Aerial Images for Distress Analysis. Nationwide, the current method of collecting pavement distress involves either driving or walking thousands of miles of pavement. The use of satellite images for quantifying pavement distress may be another source of data collection. This study will determine the adequacy of satellite technology for distress identification, determine what additional process or procedures need to be developed or declassified to access this data, and determine its benefit/cost for implementation by state highway agencies.

4.0 Roadmap Implementation

The stakeholders involved in the development of the Pavement Management Roadmap identified a plethora of research, development, and technology transfer needs that are required to solidify the role of pavement management in transportation agencies today, and to help ensure its applicability to the needs of transportation agencies in the future. As outlined in the Roadmap, this will require a coordinated plan that:

- Enhances the skills of pavement managers.
- Improves the use of existing technology and tools.
- Promotes the concepts of pavement management among decision makers and the public.
- Expands the data considered in a pavement management analysis.
- Explores the use of new tools and technology to improve the current approaches to data collection and analysis.

The Roadmap presents both the short-term and long-term priorities that will enable the pavement management community to accomplish these objectives. In total, the needs identified in the Roadmap will require $14.57 million in funding to achieve the stated goal. This amount of money is clearly beyond the capabilities of any single organization within the transportation community. Therefore, the successful implementation of the Roadmap demands a focused, cooperative approach among national and international organizations that are in a position to fund and support these types of research and outreach activities, including the FHWA, AASHTO, the National Research Academy and the Transportation Research Board (TRB), state highway agency research departments, and other industry representatives. This approach demands that:

- Funding to support pavement management initiatives is increased to meet the needs of stakeholders at all levels.
- Agencies work together to secure the necessary funding for the highest priority items.
- The pavement management community embraces the Roadmap and supports its implementation.
- Effective strategies for implementing the activities developed under this Roadmap are incorporated into each study.
- Responsibility for tracking accomplishments and pushing forward the remaining needs is assigned to a central organization.

Getting Involved

The completion of this document represents the end of the collaborative process that was followed to identify and prioritize the needs of a diverse set of stakeholders who are involved in the use of pavement management data and analysis tools to support the cost-effective management of the nation's pavement infrastructure. As documented in this report, the implementation of the Pavement Management Roadmap will rely on the creativity and resourcefulness of all those working in the pavement management community. Whether involved in the implementation and update of pavement management systems, the use of pavement management

The implementation of the Pavement Management Roadmap will rely on the creativity and resourcefulness of all those working in the pavement management community.

information for decision making, the training and advancement of practitioners' skills, or securing funding to support pavement management activities, stakeholders must get involved in supporting the activities outlined in the Pavement Management Roadmap if the community is to reach the vision for pavement management over the next 10 years.

Although the implementation of the Pavement Management Roadmap will require the participation of a wide variety of stakeholders, several recommendations are provided to help ensure that the implementation is a success at advancing pavement management initiatives. The recommendations include the following:

1. **Establish a Pavement Management Roadmap Steering Committee with responsibility for the implementation and oversight of the document.** It is recommended this Committee be organized as a subcommittee under the TRB Committee on Pavement Management (AFD10) with representation from FHWA, state and local transportation agencies, academia, associations, and private industry. This Committee should be responsible for promoting and tracking accomplishments under the Roadmap as a way to keep it in the national spotlight.
2. **Assign FHWA primary responsibility for addressing the institutional training and technology transfer initiatives identified in the Roadmap.** The FHWA, through its National Highway Institute, provides training to improve the performance of transportation agencies. In addition, the FHWA has supported the conduct of peer exchanges, national conferences, and other initiatives to advance pavement management activities. Using innovative approaches that recognize the traveling limitations that restrict agency participation in conferences and training classes, the FHWA should continue to be the primary support for these types of initiatives, as outlined in the Roadmap.
3. **Identify funding support for two to three problems statements each year through AASHTO and TRB.** This activity requires state support for the initiatives outlined in the Roadmap in order to advance the problem statements through the TRB funding process. Therefore, it is recommended that the AASHTO Joint Technical Committee on Pavements assume responsibility for this effort, for each of the next 10 years outline in the Roadmap. This recommendation in no way restricts support for additional research activities through other organizations. Instead, it merely seeks to provide a mechanism to ensure that financial support for pavement management activities remains a priority over the life of the Roadmap.
4. **Raise the profile of pavement management and its effectiveness at supporting sound asset management concepts.** As an industry, we have not placed an emphasis on promoting pavement management concepts within the transportation community. However, with the increased focus on asset management, and the importance of performance measures to improve agency accountability, agencies will increasingly rely on pavement management to support these initiatives. Therefore, the pavement management community needs to become more active in promoting its capabilities and documenting the benefits to an agency that uses these concepts to support investment decisions. The Pavement Management Roadmap can become the instrument needed to champion additional support for pavement management, as a critical tool in transportation agencies. The pavement management community needs to identify and promote a slogan that conveys the benefits, such as "*Pavement Management…the key to preserving your pavement investments*."

APPENDIX A
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APPENDIX B
PROBLEM STATEMENTS

THEME 1
PROBLEM STATEMENTS

Theme 1 – Use of Existing Technology and Tools

Problem statements in theme 1 include recommendations for technology and tools that can support traditional pavement management applications. In general, this theme includes technology and tools that are currently available today, but are in need of additional review, analysis, and/or updating prior to their implementation.

As summarized in tables B1 and B2, a total of eight short-term and two long-term needs where identified in theme 1 at a total cost of $3,030,000 ($2,180,000 for short-term needs and $850,000 for long-term needs).

Table B1. Theme 1 Prioritized Listing of Short-term Needs.

Rank	Problem Statement	Product(s)	Estimated Cost	Page
6	Best Practices for Pavement Management	Best practice guidelines	$500,000	66
7	Development of Pavement Distress Standards	Provisional AASHTO standards	$350,000	68
8	Development of Improved Methodologies for Evaluating Data Quality	Best practice guidelines	$350,000	69
10	Establish and Develop Equipment Calibration Centers and Guidelines	Regional centers, equipment calibration procedures, and operator certification program	$250,000	70
11	Comprehensive Study to Guide the Integration of Pavement Preservation and Pavement Management	Best practice guidelines	$350,000	71
19	Independent Technical Assessments of Pavement Management	Framework for assessing pavement management practices	$250,000	72
20	Pavement Management Clearinghouse	Database of equipment suppliers and contractor capabilities	$100,000	73
22	Synthesis of External Issues Driving Pavement Management	Synthesis of factors that impact pavement management practices	$30,000	74

Table B2. Theme 1 Prioritized Listing of Long-term Needs.

Rank	Problem Statement	Product(s)	Estimated Cost	Page
1	Methods of Defining and Calculating the Effect of Pavement Preservation Treatments on Pavement Life	Research report	$500,000	75
7	Investigation into the Risk, Uncertainty, and Variability in Pavement Management Decisions	Best practice guidelines and software tool	$350,000	76

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Best Practices for Pavement Management

II. RESEARCH PROBLEM STATEMENT

There is a significant need to assemble and prepare a best practices document for the operational and functional aspects of pavement management. This guide will build upon the existing AASHTO *Pavement Management Guide* and include a broad range of topics that include (but are not limited to):

- **Asset Management Principles.** Asset management and pavement management procedures and benefits.
- **Referencing Systems**. Establishing and maintaining linear referencing system, merging several linear referencing methods into a single system, and addressing alignment and boundary changes.
- **Data Collection**. Type and extent of data; data collection procedures; data collection frequency; sampling rates; data needed for network-level, project-level, forensic investigations, and research; quality control/quality assurance procedures; equipment types and capabilities; equipment specifications; and equipment certification.
- **Data Storage and Integration.** Storage requirements, needed costs, maintenance issues related to storage, storage needs and formats to maximum integration, communication, data links, and technology/system availability.
- **Data Analysis.** Procedures and processes for analyzing data to meet agency needs.
- **Performance Modeling.** What level of detail is needed (both in data collection and model development), describe when model updates are necessary (e.g., due to improvements in measurement accuracy and changes in design principles, materials, or construction practices), quantify the impacts of measurement accuracy (e.g., windshield, automated, or semi-automated), how to conduct a sensitivity analysis on the model inputs and resulting performance prediction, catalog of available performance prediction models, and how to develop, calibrate/validate, implement, and maintain prediction models.
- **Treatment Selection.** Pavement preservation and rehabilitation treatments, benefits, and limitations.
- **Presenting and Communicating Results.** Discuss recommendations for presenting pavement management results and methodologies used for communicating pavement management data to stakeholders.
- **Supporting Agency Decisions.** Use of pavement management information to support planning activities (e.g., STIP and strategic planning), allocate resources, linking network- and project-level treatment recommendations, identify organizational components that lead to successful pavement management, and provide recommendations for addressing barriers to the use of pavement management and improving agency business processes that are needed to support pavement management.

- **New Technologies.** Methodologies and procedures for evaluating and implementing emerging technologies, and coordination with and considering IT capabilities.

Tasks: The research will include the following tasks:

1. Literature search (domestic and international) on pavement management procedures and practices.
2. Develop detailed outline.
3. Develop pavement management best practices.

Final Product:
The final product of the research is a best practice guide for pavement management. Not only will this be a reference for all things related to pavement management, but it will also act as a "desk guide" for practitioners. To enhance access and implementation, it is envisioned that this guide will be developed and available through an electronic web-based format.

III. RESEARCH OBJECTIVE

The objective of this research is to provide a best practices guide for pavement management for reference, use, promotion, and to further the implementation of pavement management procedures.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $500,000
Estimated Project Duration: 36 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Development of Pavement Distress Standards

II. RESEARCH PROBLEM STATEMENT

Pavement distresses are defined, measured, and categorized differently between many state highway agencies (possibly excluding IRI). Pavement condition standards would assist in improving data quality checks for comparing performance measures, and provide guidance to equipment manufacturers and data collection service providers. AASHTO has established a number of distress protocols, but the widespread use of these protocols is uncertain. This study will identify distress to be measured, review current state practice, compare state procedures to current AASHTO protocols, identify areas not currently covered by an AASHTO protocol, develop preliminary protocols, conduct webinars or workshops to obtain state buy-in, and finalize protocol for AASHTO balloting.

Tasks: The research will include the following tasks:

1. Survey and review current state highway agency (SHA) practices regarding pavement condition standards utilized.
2. Compare SHA pavement condition standards relative to AASHTO distress protocols.
3. Identify gaps in AASHTO protocols and draft provisional standard accordingly.
4. Develop guidelines for getting the most out of contracted pavement management systems.

Final Product:
The final product of the research is a set of provisional AASHTO standards addressing SHA's needs regarding distress identification and measurement.

III. RESEARCH OBJECTIVE

The primary objective of this research is to better address SHA's needs from standardized pavement condition protocols.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $350,000
Estimated Project Duration: 24 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Development of Improved Methodologies for Evaluating Data Quality

II. RESEARCH PROBLEM STATEMENT

Pavement management recommendations are impacted by the quality of the data collected. Most agencies have recognized this issue but struggle with the lack of sophisticated methodologies to effectively and efficiently evaluate data quality and the resulting impact on pavement management decisions. The objective of this study is to develop a standard methodology that can be applied to a wide range of pavement condition data to assess quality in terms of accuracy and repeatability. The study will also demonstrate the use of the results to establish data collection guidelines (to specify required levels of accuracy) and to evaluate the impact of variability on pavement management recommendations.

Tasks: The research will include the following tasks:

1. Identify and evaluate quality control/quality assurance procedures for various pavement management data collection practices.
2. Define viable methodologies based on data precision and repeatability, collection efficiency, and cost effectiveness.
3. Develop guidelines so that an agency can apply viable methodologies into its pavement management system practices.

Final Product:
The final product of the research is development of guidelines to improve data quality in terms of collection, processing, and reporting.

III. RESEARCH OBJECTIVE

There are two specific objectives for this research. First, the research will develop standard quality control/quality assurance criteria for pavement management data collection practices. The second objective will determine how to incorporate QC/QA practices into pavement management systems.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $350,000
Estimated Project Duration: 24 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Establish and Develop Equipment Calibration Centers and Guidelines

II. RESEARCH PROBLEM STATEMENT

National calibration centers or well-established protocols or guidelines for calibrating profile, texture, noise, or ground penetrating radar (GPR) data collection are either limited or nonexistent. Strategically located calibration centers would allow for large-scale consistency in data collection and greatly improve reliability of data comparisons between equipment types and vehicles. This study will identify potential calibration sites (strategic locations and resources for establishment, maintenance, and operation), recommended equipment calibration frequencies, equipment calibration procedures, and precision and bias requirements. In the area of calibration centers, this study should reference the work and efforts developed for the FWD calibration centers.

Tasks: The research will include the following tasks:

1. Survey practitioners regarding current quality assurance/equipment calibration procedures.
2. Conduct sample size analyses to recommend how many test sections/regional test sites should be established.
3. Determine details of equipment calibration, operator certification, and amount of data to collect and review.
4. Develop practices/guidelines/specifications for equipment calibration and operator certification.

Final Product:
The final product of the research is identifying the location of regional calibration centers, calibration procedures for data collection equipment, and an operator certification program.

III. RESEARCH OBJECTIVE

There are two specific objectives for the research. First, the research will provide a synthesis of current quality assurance/equipment calibration procedures being used by practitioners in regards their data collection equipment. The second objective is establishing an equipment calibration and operator certification/training program.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $250,000
Estimated Project Duration: 12 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Comprehensive Study to Guide the Integration of Pavement Preservation and Pavement Management

II. RESEARCH PROBLEM STATEMENT

In most agencies, pavement management data collection and analysis tools were established before pavement preservation techniques were extensively used. As a result, the data that is currently collected and the project selection processes are not necessarily easily modified to include preventive maintenance treatments. However, the importance of tracking pavement preservation treatments is critical to predicting pavement performance, identifying needs, and establishing budgets. In addition, data related to pavement preservation treatments (e.g., pavement condition prior to treatment application, treatment type and thickness, and, if applicable, material type) is critical for developing performance prediction models for preservation treatments.

Tasks: The research will include the following tasks:

1. Conduct a survey of state agencies regarding best practices for integrating pavement preservation into pavement management.
2. Identify data needed to support the integration of pavement preservation into pavement management.
3. Identify levels of integration, including cost and benefits associated with each level.
4. Develop guidelines for integrating preventive maintenance into pavement management according to each level.

Final Product:
The final product of the research is guidelines for adapting pavement management systems to fully support pavement preservation activities.

III. RESEARCH OBJECTIVE

There are three specific objectives for the research. First, the research will develop a synthesis of best practices regarding how agencies integrate preventive maintenance into pavement management, identifying successful case studies and lessons learned. The second objective is to define basic levels of integration according to the state of the practice in terms of both preventive maintenance activities and pavement management practices at an agency. The final research objective is to develop guidelines that transportation agencies can use to begin integrating their preventive maintenance and pavement preservation activities.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $350,000
Estimated Project Duration: 24 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Independent Technical Assessments of Pavement Management

II. RESEARCH PROBLEM STATEMENT

The Federal Highway Association (FHWA) is a strong supporter of pavement management tools in SHAs, but the use of these tools is optional. Furthermore, there are diverse approaches being used for data collection, reporting, and analysis within those agencies using pavement management. There is also a lack of established appraisal methods for determining whether pavement management practices comply with "good practice." At the same time, agencies are facing funding constraints that limit the resources available to support pavement management.

Tasks: The research will include the following tasks:

1. Identify baseline capabilities for pavement management.
2. Survey SHAs regarding their pavement management system practices. Determine whether the baseline capabilities are being met, and if not, how any deficiencies can be addressed.
3. Develop a framework for assessing pavement management practices, including development of means to assess risk associated with specific pavement management practices relative to best practices, and recommend funding needs to address pavement management deficiencies.

Final Product:
The final product of the research is a framework for assessing pavement management practices according to an agency's activities relative to best practices.

III. RESEARCH OBJECTIVE

The primary objective of this research is to develop a means of assessing an agency's pavement management practices relative to best practices, including assessing the risk associated with specific practices so as to communicate need for improvement where applicable.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $250,000
Estimated Project Duration: 12 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Pavement Management Clearinghouse

II. RESEARCH PROBLEM STATEMENT

Technology advances in pavement distress data collection are often difficult to for an agency to monitor, evaluate, and determine implementation appropriateness. In addition, there are many resources that are of value to pavement management practitioners, but a great deal of time can be spent trying to locate the information. It would also be beneficial for transportation agencies to have a readily available list of local, regional, and national contractors and their capability of constructing the vast array of pavement preservation and rehabilitation treatments. In this manner, an agency looking to apply a specific treatment (e.g., microsurfacing or hot in-place recycling) can access a web-based clearinghouse to determine contractor capabilities. A centralized repository of equipment availability, technology advancements, resources, and contractor availability and capability is necessary.

Tasks: The research will include the following tasks:

1. Survey SHAs, equipment suppliers, and contractors regarding distress data collection equipment, contractors/supplier capabilities, and prequalification procedures.
2. Prepare a synthesis of available data collection equipment and qualified contractors.
3. Survey equipment suppliers regarding equipment capabilities for accurately measuring pavement distress.
4. Survey qualified contractors regarding capabilities specific to common pavement preservation/rehabilitation treatments.
5. Develop an online database of contractors and capabilities, allowing for a sort of vetting process for new additions.

Final Product:
The research will result in the development of an online database of equipment suppliers and treatment contractor capabilities, allowing for a sort of vetting process for new additions.

III. RESEARCH OBJECTIVE

The primary objective of this research is to develop a central resource for SHAs regarding availability of pavement condition equipment and qualified contractors in relation to their capabilities specific to pavement preservation/rehabilitation applications.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $100,000
Estimated Project Duration: 12 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Synthesis of External Issues Driving Pavement Management

II. RESEARCH PROBLEM STATEMENT

There are many factors that impact pavement management that are beyond the control of agency staff or administrators. With changes in available transportation funds, agencies have to adapt to new approaches for funding, contracting, and/or project acceptance. These external forces have undoubtedly influenced pavement management needs and priorities.

Tasks: The research will include the following tasks:

1. Conduct a survey of pavement management practitioners to determine what factors have impacted pavement management practices, as well as if and how these factors have been addressed.
2. Identify SHAs to be case studies in a more detailed assessment.
3. Develop a synthesis of findings.

Final Product:

The final product of the research is development of a synthesis of factors that impact pavement management practices, including case studies that demonstrate how state agencies have been able to address these impacts.

III. RESEARCH OBJECTIVE

Research objectives include identification of factors that impact pavement management practices at various levels (e.g., municipal, county, and state), and identification of how, and how well, these impacts are being addressed by practitioners.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $30,000
Estimated Project Duration: 9 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Methods of Defining and Calculating the Effect of Pavement Preservation Treatments on Pavement Life

II. RESEARCH PROBLEM STATEMENT

There is little information available to assist pavement managers with quantifying the effect of pavement preservation treatments on pavement life. This is especially true in light of the fact that the same treatment can be used in a preventive manner or as a stop-gap treatment. The extent of existing pavement distress, traffic level, climatic condition, treatment type, materials, and other factors can significantly impact treatment performance.

Tasks: The research will include the following tasks:

1. Conduct a survey of state of the practice regarding quantifying pavement preservation impacts on pavement life.
2. Identify roadway sections that have historical data concerning pretreatment conditions (e.g., pavement condition, pavement structure, and traffic levels), as well as construction and condition information regarding treatment type.
3. Develop pavement condition performance according to existing condition, treatment type, climate, traffic levels, and other factors.
4. Prepare a report detailing treatment performance.

Final Product:
The final product of this research will be a report documenting research findings.

III. RESEARCH OBJECTIVE

The research will quantify the impacts that pavement preservation treatments have on pavement performance, using measured field data from various geographic regions of the country.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $500,000
Estimated Project Duration: 36 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Investigation into the Risk, Uncertainty, and Variability in Pavement Management Decisions

II. RESEARCH PROBLEM STATEMENT

Pavement management systems are based on collected data (e.g., condition data, traffic data, existing layer types and thickness, and past preservation and rehabilitation treatments) that have the potential for associated errors. The analysis methods themselves are conducted using performance models that also have an associated error. Yet results of these analyses do not usually estimate the errors associated with data collection and performance prediction. The impact (or risk) associated with errors in the data collection and performance prediction processes are not well quantified. Procedures are needed to help agencies determine the amount of data needed to provide credible recommendations and to determine what level of risk (or uncertainty) is considered acceptable, in an attempt to improve levels of accountability and confidence in the performance prediction outputs from the pavement management system.

Tasks: The research will include the following tasks:

1. Identify the critical pavement management system outputs (e.g., network condition, program recommendations, and so on) that impact performance prediction.
2. Determine data and analysis needs to improve performance prediction. Identify the associated risk based on data availability and steps needed to reduce the potential of data error.
3. Develop guidelines for data collection needs and analysis for improving performance prediction.
4. Develop software tools to assess errors in the data collection and analysis procedures.

Final Product:
The final product of the research includes guidelines and software tools for assessing data quality and improving the reliability of pavement management outputs and recommendations.

III. RESEARCH OBJECTIVE

The objective of this research is to investigate the various forms of variability affecting pavement management recommendations and to develop a process for evaluating this impact and the overall effectiveness of pavement management recommendations.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $350,000
Estimated Project Duration: 24 months

THEME 2
PROBLEM STATEMENTS

Theme 2 – Institutional and Organizational Issues

The theme 2 problem statements presented in this section of the report relate to workforce development, communication, contracting, and organizational structure. The recommendations in this area are intended to address issues that include the impact of pavement management on funding and how to determine, promote, and effectively communicate the use and the benefits of pavement management.

As summarized in tables B3 and B4, a total of five short-term and six long-term needs where identified in theme 2 at a total cost of $1,660,000 ($880,000 for short-term needs and $780,000 for long-term needs).

Table B3. Theme 2 Prioritized Listing of Short-term Needs.

Rank	Problem Statement	Product(s)	Estimated Cost	Page
1	Communicating Pavement Management Information and Benefits	Sample templates, presentations, and webcasts, and/or guidelines	$250,000	79
3	Improving the Skills of Pavement Managers	Training guides, online resources, and information on career paths	$250,000	80
17	Annual Approval of SP&R Funding	Recommendations for policy revisions	$100,000	81
18	Framework for Minimizing the Delivery of Treatment Application	Best practices	$250,000	82
21	Addressing Trade-offs, Metric Issues, and Purchasing Controls/Policies	Synthesis of common issues	$30,000	83

Table B4. Theme 2 Prioritized Listing of Long-term Needs.

Rank	Problem Statement	Product(s)	Estimated Cost	Page
2	Impact of Pavement Management Investment Levels on Benefits	Best practice guidelines	$350,000	84
6	Methods to Promote Pavement Management as a Management Tool	Marketing materials	$100,000	85
13	Recommended Methodology to Calculate Pavement Asset Value and Communicate to Stakeholders	Methodology for assessing pavement value	$100,000	86
16	Suggested Topics for Pavement Management Into the Civil Engineering Curriculum	Instructors' resources	$100,000	87
17	Constant Funding for Pavement Management	Best practice guidelines	$100,000	88
18	Identify Information Technology (IT) Needs to Effectively Manage a Pavement Management System	Synthesis of common issues	$30,000	89

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Communicating Pavement Management Information and Benefits

II. RESEARCH PROBLEM STATEMENT

An important part of establishing credibility in a pavement management system is presenting recommendations in a way that resonates with the audience. Historically, pavement managers have not been effective in "telling their story" in a way that influences the decisions of executives, the public, and other external stakeholders.

Tasks: The research will include the following tasks:

1. Identify current practices incorporating pavement management with strategic planning.
2. Develop criteria for determining best practices regarding incorporating pavement management analyses into business and strategic processes.
3. Identify best practices and case studies suitable to illustrate how to successfully tie network- and project-level decisions/goals.
4. Develop guidelines documenting recommendations for using pavement management analysis results to provide meaningful planning decisions.

Final Product:
The products of the study include templates, sample PowerPoint presentations, webcasts of successful approaches, and/or guidelines for using these strategies.

III. RESEARCH OBJECTIVE

Investigate how highway agencies have successfully gained buy-in from decision makers that have led to increased use of pavement management information, investigate strategies for effectively communicating pavement management information (including the benefits of preservation), provide guidance for pavement managers responsible for making these types of presentations, and explore current methods of communication (e.g., Twitter, Facebook, and Wikipedia).

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $250,000

Estimated Project Duration: 12 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Improving the Skills of Pavement Managers

II. RESEARCH PROBLEM STATEMENT

An effective pavement manager must have both technical and social skills to be most successful; skill levels affect the final output, which in turn affects credibility and buy-in. Some of the technical skills are taught in college or through on-the-job training, such as management skills (people skills) and understanding organizational behavior. However, some aspects of a pavement manager's job are not covered in a traditional civil engineering curriculum. Agencies have three options for addressing this shortcoming; they can contract for the services needed, provide the training needed, and/or allow untrained staff to perform the activities. Furthermore, although pavement management documentation is prolific, it has not been organized in a way that is effective in training or improving pavement management operations.

Tasks: The research will include the following tasks:

1. Develop an online clearinghouse for pavement management resources, including plan documentation, case studies, open-source software, training materials, and others.
2. Define appropriate levels of training and/or aptitude for personnel working with pavement management systems.
3. Identify inexpensive, yet effective, training alternatives when funding for professional development is limited.
4. Develop guidelines for getting the most out of contracted pavement management systems.

Final Product:
The research will result in training guides to help agencies in the evaluation of fiscal and organizational impacts associated with workforce development, an online clearinghouse of useful resources, and information on career paths in pavement management.

III. RESEARCH OBJECTIVE

There are three specific objectives for the research. First, the research will develop an online clearinghouse for pavement management resources. The second objective is to define basic levels of aptitude concerning pavement management systems. The final research objective is to develop guidelines that transportation agencies can use to ensure an outsourced pavement management system meets an agency's needs.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $250,000

Estimated Project Duration: 12 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Annual Approval of State Planning and Research (SP&R) Program Funding

II. RESEARCH PROBLEM STATEMENT

The annual approval of SP&R funding does not currently match the timing of data collection and processing for most state highway agencies. When SP&R funds are available for use, they expire at the end of the year making it difficult for the SHA to expend the approved funds. This study will identify the SP&R funding restrictions, identify solutions that will meet FHWA and SHA requirements, determine recommended solutions, and suggest policy changes.

Tasks: The research will include the following tasks:

1. Identify source(s) and reason(s) for SP&R funding restrictions.
2. Identify possible resolutions for getting the most out of SP&R funds.
3. Recommend policy revisions and such to implement solutions.

Final Product:
The final product of the research is a set of recommendations for revising policy to better utilize SP&R funds in the timeframe allowed.

III. RESEARCH OBJECTIVE

The primary objective of this research is to reconcile the timeframe of agency practices with the availability of SP&R funds.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $100,000

Estimated Project Duration: 12 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Framework for Minimizing the Delivery of Treatment Application

II. RESEARCH PROBLEM STATEMENT

Often, pavement preservation/rehabilitation projects are delayed due to plan preparation, advertising, and letting. This lag time between project selection and construction may render the selected treatment ineffective due to the continued advancement or acceleration of pavement distress. There is a need to develop a process for reducing the timing between project selection and treatment application to ensure proper treatment application, maximize performance life, and reduce overall life-cycle cost.

Tasks: The research will include the following tasks:

1. Survey SHAs regarding planning and programming procedures.
2. Identify or develop procedures for reducing the time between treatment selection and application.
3. Conduct case studies to verify recommendations using data provided by SHAs.
4. Develop best practices for timely planning and programming of preservation and rehabilitation treatments.

Final Product:
The research will result in the development of best practices for the timely planning and programming of pavement preservation/rehabilitation applications.

III. RESEARCH OBJECTIVE

The primary objective of this research is to develop a best practices guide for improving the efficiency and timeliness of planning and programming operations regarding implementing pavement management recommendations, particularly with respect to pavement preservation/rehabilitation treatment applications.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $250,000

Estimated Project Duration: 12 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Addressing Trade-Offs, Metric Issues, and Purchasing Controls/Policies

II. RESEARCH PROBLEM STATEMENT

Political and organizational issues and organizational inertia can frequently impede the incorporation of improved and beneficial analysis and technological advancements into the pavement management process. In order to overcome this challenge, key issues related to the trade-offs, metric terms/issues, policies, and purchasing controls need to be determined, quantified, and presented so that more educated decisions can be made.

Tasks: The research will include the following tasks:

1. Survey practitioners regarding implementation of pavement management activities with respect to political and/or organizational encumbrances.
2. Identify common critical issues impacting implementation, especially with respect to acquiring new technology or analysis procedures and deployment of such.
3. Identify common critical issues regarding defining performance metrics and measures to meet the needs of practitioners and decision-makers.
4. Prepare a synthesis of findings.

Final Product:
The final product of the research is a synthesis of common issues encountered in pavement management with respect to political and/or organizational impacts on policy, performance measures, implementation of new practices and activities, and so on.

III. RESEARCH OBJECTIVE

The primary objective of this research is to understand the common critical issues surrounding political and/or organizational change on pavement management policy.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $30,000

Estimated Project Duration: 9 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Impact of Pavement Management Investment Levels on Benefits

II. RESEARCH PROBLEM STATEMENT

As agency budgets tighten, pavement management data collection activities (which typically represent the largest part of the budget for pavement management activities) are at risk of budget cuts. However, since the relationship between expenditures for data collection and analysis tools and pavement management outputs is not well understood, the financial impact and/or risk of budget cuts cannot be communicated. For example, if an agency cuts the data collection budget by 50 percent, an agency could respond by extending the frequency with which data are collected or be reducing the amount of data collected in each cycle. The consequences associated with each of these options are not well understood and there is no known basis for deciding how to address this challenge.

Tasks: The research will include the following tasks:

1. Survey practitioners for information regarding funding levels for pavement management data collection, number of network miles, and budget for preservation, rehabilitation, and reconstruction.
2. Analyze survey results to determine if any trends exist between funding for pavement management and funding for pavement preservation/rehabilitation/reconstruction.
3. Conduct risk analyses for cost effectiveness of perceived trends.
4. Develop guidelines allowing practitioners to illustrate how funding levels impact pavement management and its practices.

Final Product:

The final product of the research is a set of guidelines for determining how funding impacts pavement management practices, illustrating the risks or benefits associated with changes in levels of funds allocated to pavement management/preservation activities.

III. RESEARCH OBJECTIVE

There are three specific objectives for the research. First, the research will determine the relationship between agency funding and pavement management practices. The second objective is to define the risk or benefit associated with whether adequate funding is provided to conduct pavement management/preservation work. The final research objective is to develop guidelines that will illustrate for practitioners how pavement management is affected by funding and the impact such effects can have.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $350,000

Estimated Project Duration: 24 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Methods to Promote Pavement Management as a Management Tool

II. RESEARCH PROBLEM STATEMENT

Pavement management is an important tool to help agencies keep a long-term perspective when managing assets. It can be used to show impacts of different strategies, estimate needs, set and monitor performance targets, and evaluate changes in design, materials, or construction. But its value to agencies is not always well understood, especially among executives and elected officials with short-term positions. Therefore, what is needed is a public relations campaign that raises the profile of pavement management and communicates the wide-ranging benefits it provides an agency.

Tasks: The research will include the following tasks:

1. Identify various internal and external audiences—considering both marketing and engineering perspectives—affected by pavement management.
2. Survey practitioners regarding how pavement management is promoted internally and externally.
3. Identify effective ways of promoting pavement management to garner internal, public, and official buy-in and support.
4. Develop a marketing/public relations campaign(s) to raise the profile of pavement management activities and their associated benefits to the public, officials, and the practicing agency.

Final Product:
The research will result in marketing materials that can be used to demonstrate the benefits of pavement management to all stakeholders.

III. RESEARCH OBJECTIVE

There are two specific objectives for the research. First, the research will identify effective ways of promoting pavement management practices internally and externally to an agency. The second objective is developing a marketing/public relations campaign to encourage pavement management activities by an agency.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $100,000
Estimated Project Duration: 12 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Recommended Methodology to Calculate Pavement Asset Value and Communicate to Stakeholders

II. RESEARCH PROBLEM STATEMENT

Asset management systems have traditionally been required to answer the following fundamental questions: What assets do we have? Where are they? What condition are they in? A fourth, but equally fundamental, question now also exists: What is the value of our assets both today and expected over the life cycle? This fourth question has become particularly relevant with the advent of Government Accounting Standards Board Statement 34 (GASB 34), which is a past based approach, as compared to current and future based approaches. GASB 34 uses historical data to calculate asset value, and if this is not available, current replacement costs are "deflated" using a construction price index to estimate historic cost. Current based methods include replacement cost, written down replacement cost and net salvage value. Future based methods require performance models and include productivity realized value, salvage value, and market value. Application to real networks has been limited but indicates substantial differences in calculated asset value, depending on method, age of the asset, predicted performance, and various other factors. Agencies who track and report asset value over time do not have consistent, understandable, and widely accepted methodology.

Tasks: The research will include the following tasks:

1. Carry out a review of existing literature, national and international, on asset valuation methodology for civil infrastructure and particularly how it has been applied to pavements at the strategic, network and project levels.
2. Identify the positive features and the shortcomings of these methodologies.
3. Review the (full accrual accounting) requirements of GASB 34, and the various ways in which GASB 34 can be reported.
4. Prepare recommendations for a consistent, understandable and acceptable methodology for pavement asset valuation which can be used for reporting under GASB 34, but can also have wider application or use by stakeholders if possible.

Final Product:
The final product of this study is a methodology for assessing pavement value for reporting to GASB 34.

III. RESEARCH OBJECTIVE

The objective of this study will be to develop an asset valuation methodology for civil infrastructure, particularly on how it applies to pavements at the strategic, network, and project level.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $100,000
Estimated Project Duration: 12 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Suggested Topics for Pavement Management into the Civil Engineering Curriculum

II. RESEARCH PROBLEM STATEMENT

There is not sufficient emphasis on pavement management in civil engineering curricula. As a result, there is a steep learning curve for new practitioners. Therefore, there is a need to raise the awareness of pavement management concepts in the existing college curricula.

Tasks: The research will include the following tasks:

1. Survey and create a synthesis of current college curricula regarding transportation engineering and management.
2. Survey practitioners' needs in regards to new employee knowledge and skills.
3. Develop teaching/learning resources to increase the level of awareness among instructors and students.

Final Product:

The final product of the research is a set of instructors' resources for incorporating pavement management principles and concepts into college curricula.

III. RESEARCH OBJECTIVE

There are two specific objectives for the research. First, the research will determine what level of education regarding pavement management practices and principles would be beneficial to new employees. The second objective is developing resources instructors can use to incorporate pavement management-related education into their syllabi.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $100,000
Estimated Project Duration: 12 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Constant Funding for Pavement Management

II. RESEARCH PROBLEM STATEMENT

Inconsistent levels of funding make it difficult for pavement management staff to keep pavement conditions at a consistent level and predict future needs (e.g., pavement preservation, rehabilitation, and reconstruction) of the system. Additionally, it is difficult to maintain a consistent level of work for designers and contractors.

Tasks: The research will include the following tasks:

1. Survey SHAs regarding approaches used for fund allocation.
2. Summarize the advantages/disadvantages of each approach.
3. Quantify the impacts of suboptimal allocations.
4. Identify the monetary needs for a consistent pavement management work program to allow agencies to optimize pavement treatments and funding.
5. Develop best practices guidelines and recommendations.

Final Product:
The research will result in the development of guidelines for recommending allocation of funds according to objective pavement management data.

III. RESEARCH OBJECTIVE

The primary objective of this study is to develop a synthesis of practice for allocating funds for pavement preservation and pavement rehabilitation.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $100,000
Estimated Project Duration: 12 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Identify Information Technology (IT) Needs to Effectively Manage a Pavement Management System

II. RESEARCH PROBLEM STATEMENT

As agencies seek to achieve efficiencies in information technology practices, users of advancing technologies are experiencing challenges for accessing, manipulating, and using technology associated with internal IT departments. Often, technology advancements to address pavement management needs are impeded due to potential limitations in network capabilities, IT personnel understanding of the issues, or pavement managers' lack of knowledge on IT limitations, procedures, and roles.

Tasks: The research will include the following tasks:

1. Survey practitioners regarding the role IT departments play in acquiring, implementing, and deploying new pavement management information technology.
2. Identify common goals, needs, and gaps between pavement managers and IT managers.
3. Develop synthesis for coordinating IT needs and addressing common obstacles to satisfy both pavement management needs and IT management.

Final Product:

The final product of the research is a synthesis that identifies common critical issues encountered when acquiring, implementing, and deploying new pavement management information technology, and how to work with IT management to more effectively communicate needs.

III. RESEARCH OBJECTIVE

The primary objective of this research is to identify and address common issues encountered between IT management and pavement management as it pertains to effectively meeting the goals and objectives of pavement management policy and practice.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $30,000
Estimated Project Duration: 9 months

THEME 3
PROBLEM STATEMENTS

Theme 3 – The Broad Role of Pavement Management

Theme 3 includes problem statements that go beyond the standard functions of pavement management and include such areas as pavement design, impact of increasing load limits on pavement performance, and asset management.

As summarized in tables B5 and B6, a total of five short-term and five long-term needs where identified in theme 3 at a total cost of $2,850,000 ($1,550,000 for short-term needs and $1,300,000 for long-term needs).

Table B5. Theme 3 Prioritized Listing of Short-term Needs.

Rank	Problem Statement	Product(s)	Estimated Cost	Page
2	Development and Use of Effective Performance Measures	Best practice guidelines	$250,000	92
12	Pavement Management Data Mining: Improving Current Uses and Leveraging New Applications of Pavement Management Data	Best practice guidelines	$350,000	94
14	Load Limit Impacts on Pavement Performance	Methodology and best practice guidelines	$500,000	95
15	Developing and Supporting a Pavement Management Business Plan	Training, implementation strategies, and marketing plan	$350,000	97
16	Use of Pavement Management Information for National Reporting	Best practice guidelines	$100,000	99

Table B6. Theme 3 Prioritized Listing of Long-term Needs.

Rank	Problem Statement	Product(s)	Estimated Cost	Page
3	Using Pavement Management Data to Support Design Activities	Best practice guidelines	$350,000	100
9	National Funding Allocations That Account for State Priorities	Formula or benchmark guidelines	$250,000	101
11	Identify Data Needs to Support Other Processes	Best practice guidelines	$350,000	102
14	Methodologies to Reliably Support Innovative Contracting	Best practice guidelines	$250,000	103
20	Impact of Earmarks on Pavement Performance	Research report	$100,000	104

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Development and Use of Effective Performance Measures

II. RESEARCH PROBLEM STATEMENT

To be most effective, pavement management should exist within an asset management framework that supports the integrated analysis of project needs and investment decisions. Agencies that have adopted asset management principles rely on performance management as a way of communicating needs, setting performance targets, and reporting progress. To date, a disconnect exists between performance measures used for strategic purposes and those that are reported in a pavement management system (e.g., IRI). In addition, many pavement management systems do not currently include measures needed to support the selection of pavement preservation treatments or the documentation of benefits for use in a pavement management cost/benefit analysis. Such measures might include maintenance patching or the consideration that pavement preservation might defer the need to patch. In some cases, existing performance measures are negatively impacted by the application of pavement preservation activities, such as an increase in roughness associated with the use of chip seals, so guidance must be provided on how to handle these instances.

Tasks: The research will include the following tasks:

1. Perform a literature review and survey of SHAs to synthesize performance measure terminology and targets, as well as thresholds and triggers.
2. Develop guidelines for determining effective performance measures and how to report measures according to the goals perceived by the target audience (e.g., technical, nontechnical, departmental, and political).
3. Perform a gap analysis of typical components and needs of pavement management systems compared to those of asset management practices, and identify strategies for closing the gap.
4. Develop guidelines for implementing a pavement management system with the intention of ultimately integrating it into an asset management plan.

Final Product:

The research will result in the development of a guidelines document recommending how to develop and/or synergize pavement management system performance measures to strategic initiatives. Additional products of this research will include definitions that will improve the consistency in the use of relevant terms, a synthesis of current pavement performance measures, and recommendations for using performance measures effectively.

III. RESEARCH OBJECTIVE

Under this study, states with successful asset management systems and their impact on pavement management will be documented, investigation of the connection between strategic and operational performance measures will be conducted, and guidelines on the use of pavement management measures to support strategic initiatives will be developed. Innovative performance measures should be considered during this research. For instance, the use of nontraditional measures, such as the change in economic value over time, may be explored. Guidelines should also be developed

for identifying effective performance measures for evaluating pavement preservation treatments in a pavement management system. Examples in which pavement management information has been used successfully for goal setting will be provided.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $250,000
Estimated Project Duration: 12 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Pavement Management Data Mining: Improving Current Uses and Leveraging New Applications of Pavement Management Data

II. RESEARCH PROBLEM STATEMENT

There is an untapped potential to make greater use of pavement management data to better address current agency needs and to provide insight into new areas (e.g., asset value, new design methods, improved construction practices, corridor studies, forensic investigation, and impacts of weight limits on performance). However, for these types of analyses to take place, it is important that data from related data sources are better leveraged.

Tasks: The research will include the following tasks:

1. Survey practitioners for types of pavement management data they collect.
2. Identify new areas where pavement management data can be utilized (e.g., asset value, new design methods, forensic investigation, and improved construction practices).
3. Develop case studies that illustrate the uses of pavement management data for the areas identified under task 2.
4. Develop guidelines (including case studies identified in task 3) on how to use pavement management data for addressing the areas identified in task 2.

Final Product:
The final product of the research is guidelines for using pavement management data to address the needs of other departments within an agency.

III. RESEARCH OBJECTIVE

There are two specific objectives for the research. First, the research will identify what pavement management data is collected. The second objective is to define how to leverage such data for use in other departments within an agency.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $350,000
Estimated Project Duration: 24 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Load Limit Impacts on Pavement Performance

II. RESEARCH PROBLEM STATEMENT

State legislatures are regularly faced with requests for load limit exemptions for a portion of the road system and often grant these requests without understanding the impacts to the road system. Nationally, there is pressure to raise the current 80,000 pound load limit on interstate highways to 97,000 pounds. In addition, agencies are faced with requests for permission to carry oversized loads or to levy fines to drivers of overweight vehicles. However, the impact of these heavy loads on performance measures, such as future pavement conditions, maintenance costs, and remaining service life, is not well understood and may be difficult for agency personnel to readily quantify.

Traditional methods of predicting pavement performance for pavement management purposes have utilized historical pavement condition data. A statistical analysis using regression is typically performed on pavement condition data to estimate changes in pavement condition with time. The historical data are assumed to be reliable predictors of future performance. However, if increased load limits are allowed on existing pavements, it is reasonable to expect that existing pavements will deteriorate at an accelerated rate since they were not designed to accommodate these weights. Future maintenance and rehabilitation costs may also increase to reflect the increased deterioration. Further, increased pavement thicknesses may be required for agencies designing new pavements or for rehabilitating existing pavements to accommodate the new load limits.

Tasks: The research will include the following tasks:

1. Identify one or more performance metrics that can be used to quantify the impact of increased loads (e.g., pavement condition, remaining service life, and increased maintenance costs).
2. Develop a methodology that illustrates the use of existing pavement management data to quantify the impact of changes in load limits on each of the selected performance metrics. Existing tools should be utilized as much as possible in developing the methodology.
3. Conduct trial applications of the methodology using data provided by SHAs.
4. Verify the methodology using data from an agency that recently increased load limits and has data that could be used to document impacts. Verification should include historical data from an agency where load limits have been increased at least 5 years prior to the start of the study. Comparisons should be made between the predicted impacts and the actual impacts as measured through pavement management or other methods.
5. Develop guidelines (including case studies) on using pavement management data for quantifying the impact of load limit increases, on how SHAs can incorporate developed procedures into the pavement management process, and how to verify/calibrate developed models to local conditions.

Final Product:
The research will result in the development of a methodology for evaluating the impact of load limit changes and guidelines on use of the methodology.

III. RESEARCH OBJECTIVE

There are three specific objectives for the research. First, the research will identify performance measures that can be used to quantify the impacts to the agency of increased vehicle loading. The second objective is the development of a methodology that can be applied using existing data to quantify the impacts associated with heavy vehicles loads. The final research objective is the development of guidelines that transportation agencies can use to implement the methodology.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $500,000
Estimated Project Duration: 36 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Developing and Supporting a Pavement Management Business Plan

II. RESEARCH PROBLEM STATEMENT

Pavement management has been around for decades, but in some ways the integration of pavement management into the core business function of many agencies is very immature. Pigeonholing pavement management as the collection and reporting of pavement condition is too narrow, and the assumption that pavement management is a panacea of everything related to pavements is doomed to fail as too broad. Defining the focus for pavement management and defining and developing necessary skills should be documented in the form of a pavement management business plan. Although the purpose is to show the strong ties needed between pavement management and agency business plans, the focus should include a broad array of functions ranging from simplistic to very complex and anticipate use by established practitioners, pavement management newcomers, and agency executives.

The term "pavement management" means very different things to different people. Pavement management practitioners can use their systems for the traditional pavement condition data collection and reporting, generation of rehab/maintenance plans, support of design, materials, and construction activities, and support of research, among others. However, having all of these tasks greatly broadens the demands on pavement management systems and the practitioners. These demands also greatly broaden the skills needed in pavement management work groups to include communications, statistics, economics, electronics, computer science, physics, etc. The potential for a more unified pavement management community with targeted goals and business integration strategies should mature the field.

Tasks: The research will include the following tasks:

1. Define core business functions of pavement management.
2. Conduct a survey of SHAs to identify the status of pavement management systems in accordance with the core business functions.
3. Determine barriers that are preventing the success and develop plans to help address incorporation of the core business functions. This task could include training, institutional issues, staffing, appropriate data, competing requirements, and technology needs.
4. Determine what tangential areas are best for expansion and what practitioners need to accomplish incorporation of the core business functions.
5. Develop appropriate training, implementation strategies, marketing plan, etc. to promote and facilitate coordination between agency vision, mission, and pavement management.

Final Product:

Training, implementation strategies, marketing plan, etc. to promote and facilitate coordination between agency vision and mission and pavement management.

III. RESEARCH OBJECTIVE

The research should provide means to create practitioners with the skills to more fully understand pavements and associated technologies and skills to communicate that knowledge for business and marketing decisions. Presumably, in an altruistic sense, this research will result in better decisions by the agencies that can be strongly supported by pavement management and practitioners and ultimately by the users of transportation.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $350,000
Estimated Project Duration: 24 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Use of Pavement Management Information for National Reporting

II. RESEARCH PROBLEM STATEMENT

In many states, Highway Performance Monitoring System (HPMS) data and pavement management data are collected by separate divisions or reported by someone not involved in the data collection process. In some cases, the HPMS data are "passed off" without regard for the accuracy of reporting the information. As a result, there can be issues with data quality between what is collected by pavement management and what is reported to FHWA through the HPMS process. Additionally, there is an inefficient use of resources if similar data are being collected by two different groups within the same agency. There is also generally less buy-in or credibility in the HPMS data than in the pavement management data. Furthermore, HPMS data does not always represent data that drives an agency's project and treatment selection processes.

Tasks: The research will include the following tasks:

1. Identify example SHAs who could supply both HPMS and pavement management system data.
2. Compare and identify data inconsistencies or quality issues that would keep an agency's pavement management data from meeting HPMS requirements.
3. Develop guidelines for standardizing data elements to meet both pavement management and HPMS needs.

Final Product:
The final product of the research is development of guidelines for a standardized method of reporting this information.

III. RESEARCH OBJECTIVE

There are two specific objectives for the research. First, the research will identify common inconsistencies between pavement management and HPMS data needs. The second objective is to develop guidelines for standardizing data collection and reporting to satisfy both requirements.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $100,000
Estimated Project Duration: 12 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Using Pavement Management Data to Support Design Activities

II. RESEARCH PROBLEM STATEMENT

Historically, pavement management activities have been implemented to support activities associated with the planning and programming of rehabilitation projects and preservation treatments. However, information from pavement management could be used to better support design functions if data integration and data quality issues are addressed. In this regard, additional tools are needed to use pavement management data to support the prediction of pavement performance (including the structural aspect) as are guidelines for using this information to locally calibrate performance prediction models using measured data. In addition, with the upcoming release of AASHTO DARWin-ME, more and more states will be looking toward their pavement management data to aid in the calibration process. The communication between the pavement design and pavement management staff will be critical to fully capture the benefits of mechanistic-empirical based design and the predicted outcomes. A process to compare/check the predicted performance from mechanistic-empirical based design to the performance predicted from the pavement management system is needed.

Tasks: The research will include the following tasks:

1. Survey practitioners regarding how implementing AASHTO DARWin-ME has impacted, or compares to, their pavement management practices and/or recommendations, and how such impacts have been addressed.
2. Develop guidelines for determining the compatibility of prediction and recommendations from both the pavement management system and AASHTO DARWin-ME.
3. Develop software to reconcile and calibrate performance prediction models using pavement management and AASHTO DARWin-ME.

Final Product:

The research will result in the development of guidelines for determining the compatibility of pavement performance prediction between a pavement management system and AASHTO DARWin-ME, as well as the development of software to reconcile and calibrate the performance prediction models within a pavement management system and AASHTO DARWin-ME.

III. RESEARCH OBJECTIVE

There are two specific objectives for the research. First, the research will develop guidelines for determining the compatibility of pavement management and AASHTO DARWin-ME prediction and recommendations, and the second objective will develop guidelines and software tools for reconciling and calibrating pavement management systems and AASHTO DARWin-ME performance prediction models.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $350,000
Estimated Project Duration: 24 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

National Funding Allocations that Account for State Priorities

II. RESEARCH PROBLEM STATEMENT

Each state has its own way of prioritizing needs and allocating funding. As a result, there will be differences in the pavement performance measures that can be accomplished within each agency. However, there is a tendency toward national comparisons of pavement performance that do not account for these differences.

Tasks: The research will include the following tasks:

1. Survey SHAs regarding allocation of state funds toward highway transportation, conditions of their networks, and pavement management priorities.
2. Correlate SHA objectives and priorities to network condition and annual budget and expenditures.
3. Develop a methodology for determining a SHAs' success in terms of pavement condition relative to funding.

Final Product:
The final product of the research is a formula or set of benchmark guidelines for comparing SHA pavement management practices relative to funding priorities.

III. RESEARCH OBJECTIVE

There are two specific objectives for the research. First, the research will correlate SHA funding priorities with pavement management activities. The second objective is to formulate a sort of common denominator for all SHAs so as to appropriately compare relative success of pavement management practices.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $250,000
Estimated Project Duration: 12 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Identify Data Needs to Support Other Processes

II. RESEARCH PROBLEM STATEMENT

As data collection has become more sophisticated, the demand on data contained within the pavement management system has increased. This increase has been noted by pavement performance data for use in calibration of the Mechanistic-Empirical Pavement Design Guide (MEPDG), the HPMS reassessment, warranties, public-private partnerships, and forensic studies, among others. An assessment of what and how pavement management data can be used to support these various applications is needed.

Tasks: The research will include the following tasks:

1. Identify applications that can benefit from the use of pavement management data.
2. For the identified applications, determine the type of data, the amount of data, and the level of detail needed to support the various applications.
3. Determine the cost/benefit of collecting and incorporating the data into the pavement management system if not already present.
4. Quantify the risk of managing known versus unknown problems.
5. Conduct case studies to demonstrate benefit of using pavement management data in other applications.
6. Develop guidelines that demonstrate how pavement management data can be used in other applications.

Final Product:
Guidelines on what and how data contained within a pavement management system can be used to support other applications within a highway agency.

III. RESEARCH OBJECTIVE

The objectives of this research include identifying applications that could benefit from pavement management data, identifying current data that can be used to improve/enhance these applications, identifying gaps in needed data, and providing guidelines on how to better utilize pavement management data in other applications.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $350,000
Estimated Project Duration: 24 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Methodologies to Reliably Support Innovative Contracting

II. RESEARCH PROBLEM STATEMENT

With increases in the use of warranty, concessionary, and public-private partnerships, as well as other innovative contracting processes, changes in the use of pavement management data can be expected. For instance, historical pavement performance data and forecasted conditions may be used to set acceptable condition levels and to determine whether contractual performance requirements have been satisfied. As a result, a higher level of reliability is required of the data than is needed for traditional processes, and so data collection processes may need to be modified.

Tasks: The research will include the following tasks:

1. Identify data needs for managing innovative contracting projects, such as critical data for measuring performance.
2. Determine the impacts innovative contracting has on pavement management practices, and develop recommendations for accommodating these impacts (i.e., selecting applicable performance measures).
3. Identify means for collecting data to support performance measures.
4. Develop guidelines for ensuring pavement management needs are satisfied by innovative contracted projects.

Final Product:
The final product of the research is a set of guidelines for ensuring pavement management needs are satisfied by innovative contracting practices.

III. RESEARCH OBJECTIVE

There are three specific objectives for the research. First, the research will identify the various impacts innovative contracting has on pavement management systems. The second objective is to determine how to account for the impacts innovative contracting has on pavement management systems; for example, developing performance metrics and applicable data to measure said impacts. The final research objective is to develop guidelines for ensuring pavement management needs are satisfied by innovative contracting practices.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $250,000
Estimated Project Duration: 12 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Impact of Earmarks on Pavement Performance

II. RESEARCH PROBLEM STATEMENT

Earmarks can consume considerable SHA funding, leaving less funds to address the needs of the entire highway system. Some earmarks require bond indebtedness that has a long lasting obligation to the SHA. When earmarks are large in dollars or numbers, they significantly alter the ability of the SHA to address pressing needs such as pavement preservation.

Tasks: The research will include the following tasks:

1. Survey practitioners and prepare a synthesis regarding the impact earmarks have on long-range programming and planning.
2. Reconcile SHA network needs with earmarks relative to funds allocated.
3. Identify any trends between the status of network condition in the wake of large expenditures for earmarked projects.
4. Prepare a report that summarizes findings.

Final Product:

The final product of the research is a report analyzing the impacts earmarks have on a pavement management program and agency priorities and goals in terms of services provided by such earmarks, as well as any reduction in services provided according to the recommendations based on pavement management information.

III. RESEARCH OBJECTIVE

The primary objective for the research is to determine the impact earmarks have on an SHA achieving its network condition goals and/or addressing recommendations provided by its pavement management system.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $100,000
Estimated Project Duration: 12 months

THEME 4
PROBLEM STATEMENTS

Theme 4 – New Tools, Methodologies, and Technology

The problem statements in theme 4 are related to needs for research and development leading to new tools, methods, and technology to support pavement management. In general, problem statements included in this theme address concepts that are not readily available and will require a higher level of research, analysis, and development prior to implementation.

As summarized in tables B7 and B8, a total of five short-term and eleven long-term needs where identified in theme 4 at a total cost of $7,030,000 ($1,930,000 for short-term needs and $5,100,000 for long-term needs).

Table B7. Theme 4 Prioritized Listing of Short-term Needs.

Rank	Problem Statement	Product(s)	Estimated Cost	Page
4	Development of Automated Condition Data Processing Tools	Software	$800,000	108
5	Methods to Quantify the Benefits of Pavement Management	Synthesis of state practice	$30,000	109
9	Improving Factors Considered in Project and Treatment Selection Decisions	Best practice guidelines	$250,000	110
13	Analysis of Trade-Offs Associated with Alternate Methods of Data Collection	Software	$350,000	111
23	Pavement Management in a Changing World	Best practice guidelines	$500,000	113

Table B8. Theme 4 Prioritized Listing of Long-term Needs.

Rank	Problem Statement	Product(s)	Estimated Cost	Page
4	Performance Models that Consider Series of Treatments	Best practice guidelines	$500,000	114
5	Method for Effectively Modeling Structural Condition	Best practice guidelines	$350,000	115
8	Automation of Surface Texture Characteristics	Best practice guidelines, specifications and procedures	$500,000	116
10	Identifying Strategies for Incorporating Emerging Technologies into the Pavement Management System	Best practice guidelines and software	$350,000	117
12	Quantifying the Cost of Pavement Use	Best practice guidelines and software	$350,000	118
15	Develop NDT for Measurement of In-Place Material Properties	Data collection equipment and analysis procedures/software	$800,000	119
19	Quantifying the Benefits of Pavement Research	Methodology to evaluate research investments	$250,000	120
21	Develop Default Models for Low-Volume Roads	Pavement performance models and design procedures	$350,000	121
22	Impact of Climate Change on Performance Prediction	Best practice guidelines	$350,000	122
23	Development and Integration of Wireless Sensors with PMS	Research reports, best practice guidelines, and prototype sensors	$500,000	123
24	Use of Aerial Images for Distress Analysis	Best practice guidelines and software	$800,000	125

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Development of Automated Condition Data Processing Tools

II. RESEARCH PROBLEM STATEMENT

Improvements to current tools for automating the processing of some measures of pavement evaluation are needed to accelerate the rate at which survey results become available and to improve the consistency and reliability of the information. In particular, improvements are needed to the processing of surface distress data, GPR, and rutting. For cracking, algorithms are needed for 1-mm 3-D data systems; for rutting, a methodology is needed to interpret thousands of points of transverse profile; and for GPR, algorithms are needed for improved thickness detection.

Tasks: The research will include the following tasks:

1. Identify problems and performance needs (including acceptable levels of precision and bias) for data processing of automated pavement crack detection, transverse profile, and GPR.
2. Develop new algorithms to fully automate crack and rut detection based on 1-mm 3-D data systems.
3. Improve thickness detection algorithms for GPR devices.

Final Product:
The final product of the research is a modular software package incorporating new or improved algorithms for cracking and rutting detection and thickness determination using GPR.

III. RESEARCH OBJECTIVE

There are two specific objectives for the research. First, the research will develop fully automated crack and rut detection algorithms, and the second objective is to develop improved thickness detection algorithms for GPR devices.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $800,000
Estimated Project Duration: 48 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Methods to Quantify the Benefits of Pavement Management

II. RESEARCH PROBLEM STATEMENT

Pavement management practitioners can usually describe the benefits associated with pavement management, particularly in terms of effective use of agency funding and improvements in pavement condition. However, the potential cost saving to the agency associated with the use of pavement management information by other stakeholders (such as design) is often nebulous and esoteric. In addition, social benefits (e.g., user costs, sustainability, livability, and environmental) are typically ignored when considering benefits associated with pavement management. Thus, the direct and indirect benefits of pavement management must be quantified so that cost savings can be used as justification for future investment in pavement management and data collection activities. Benefits that might be incorporated into this study may include better data access, improved decision making, user cost savings (e.g., vehicle operating costs), improved design features, and reduction in maintenance costs.

Tasks: The research will include the following tasks:

1. Identify links and prioritize the relative significance of these inter-relationships between pavement management and areas (e.g., economic development, safety, and environment) other than facilities' condition.
2. Conduct a survey of practitioners (both public and private) to determine how these links are quantified (e.g., user costs) and accounted for in decision making and presented in reports.
3. Prepare a synthesis of findings, including case studies.

Final Product:
The research will result in a synthesis of the state of the practice to account for social, economic, and environmental impacts as determined using pavement management data.

III. RESEARCH OBJECTIVE

The research will provide the means to quantify and account for benefits and consequences determined by pavement management systems in terms of various other areas, such as social, economic, and environmental impacts.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $30,000
Estimated Project Duration: 9 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Improving Factors Considered in Project and Treatment Selection Decisions

II. RESEARCH PROBLEM STATEMENT

Ideally, the recommendations for project and treatment selection closely match the activities that are funded for construction. However, this has not always been the case. One of the factors that have impacted the degree to which pavement management recommendations are followed is the correlation between treatment selection factors considered by the pavement management system and those considered by personnel in the field. To better improve this match, it is important that the pavement management analysis begin to consider factors that have not been taken into account in the past, including safety, congestion, sustainability (environment), life-cycle costs including user costs, and other emerging issues.

Tasks: The research will include the following tasks:

1. Develop a survey for practitioners to determine what factors are used by field personnel in deciding which pavement preservation treatment regimen to administer.
2. Reconcile field factors with those considered by the agency's pavement management system.
3. Develop a methodology for considering factors that have not been taken into account in the past (e.g., safety, congestion, environment, and other emerging issues).
4. Develop best practices for coordinating treatment selection and application timing between those recommended by the pavement management system and those determined by field personnel.

Final Product:
The research will result in the development of a process for evaluating the decision factors used in the pavement management treatment selection process and guidelines for addressing any existing gaps in the criterion.

III. RESEARCH OBJECTIVE

There are three specific objectives for the research. First, the research will provide means for SHAs to reconcile factors considered by their field personnel with respect to pavement management system recommendations. The second objective is to develop a methodology that considers factors that have not been taken into account in the past. The final research objective is to develop guidelines that assist in resolving potential recommendation differences between pavement management system and field personnel.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $250,000
Estimated Project Duration: 24 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Analysis of trade-offs associated with alternate methods of data collection

II. RESEARCH PROBLEM STATEMENT

As new technology comes along to aid in the pavement management efforts, many agencies will be contemplating whether they should switch from their current practices and adopt new ones. These may include new data collection equipment, analysis procedures, software, etc. Due in part to limited budgets, but also as a practical matter, agencies will need to determine which of their current activities can be modified or even eliminated as a result of this new technology. Procedures that allow an agency to calculate the pros and cons of switching technologies would be very beneficial. This tool would allow them, for example, to make a case for purchasing new data collection equipment, if they can show that other, manual procedures can be eliminated. One example might be the impact of switching from a semi-automated distress analysis procedure to a fully automated procedure. Potential questions that could be addressed include: What equipment would be needed? What costs would be incurred? Could current staff be reduced? Could the data be turned around more quickly? Would the results be more accurate? Could a larger sample of the network be done? Would it be worth the added cost, time, and effort?

Tasks: The research will include the following tasks:

1. Determine the (ideal) core functions of pavement management. This task may include identifying what data is currently being collected, what equipment and analysis procedures are being used, and what little used new technology might be available for a state agency to consider.
2. Determine if those core functions are broadly being met.
3. If the core functions are not being met, then determine what barriers are preventing the success and develop plans to help address those. This plan may include training, addressing institutional issues, determining needed staffing levels, identify appropriate data to be collected, identify competing requirements, and determining technology needs.
4. Determine what tangential areas are best for expansion of the core functions and what practitioners need to do to accomplish expansion of the core functions.
5. Conduct case studies with specific agencies looking to upgrade equipment or change pavement management activities, and develop an analysis tool to illustrate such outcomes as trade-offs, pros/cons, and added costs or savings. The developed analysis tools would assist in providing the impact proposed changes would have on the agency's budget, labor force, analysis schedule, etc.
6. Develop appropriate training, implementation strategies, marketing plan, etc. to promote and facilitate coordination between agency vision, mission, and pavement management.

Final Product:

The final product would include an analysis tool for evaluating alternative methods/equipment for collecting pavement condition data, training on use of the developed tool, strategies for implementing equipment/method modifications, and guidelines for how to market, promote and facilitate proposed modifications.

III. RESEARCH OBJECTIVE

Advance the tools, methodologies, and practices of state highway agencies to incorporate equipment and analysis advancements that provide improved, cost-effective data collection procedures and techniques.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $350,000
Estimated Project Duration: 24 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Pavement Management in a Changing World

II. RESEARCH PROBLEM STATEMENT

Pavement management must operate in an environment that is constantly changing. For instance, there are continual changes in leadership, and each change typically brings new agendas. There are also unfunded mandates, changes in freight weights and movements, increased data requirements, scope creep, and changes in regulations that must be addressed. Transportation agencies have limited experience quantifying and communicating the impact of these changes on the highway network.

Tasks: The research will include the following tasks:

1. Identify potential external impacts that impact the pavement management process (e.g., funding, pavement condition, data collection, and state and federal regulations).
2. Survey SHAs to determine trends and potential impact on pavements (i.e. increased damage and changes in decision).
3. Quantify the benefits of different funding scenarios.
4. Show impact on network strategies.
5. Create metrics to allow flexibility to deal with changing priorities.
6. Develop guidelines (including an analysis tool) that can be used to quantify changes and demonstrate impact on pavement performance.

Final Product:
The final product of this research will be guidelines and an analysis tool for quantifying and communicating the impact of external changes on pavement management systems.

III. RESEARCH OBJECTIVE

A number of external impacts can affect the pavement management process (e.g., pavement condition, funding levels, and agency preservation/rehabilitation priorities). The objective of this study is to provide highway agencies the ability to access and communicate these impacts to stakeholders.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $500,000
Estimated Project Duration: 36 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Performance Models that Consider Series of Treatments

II. RESEARCH PROBLEM STATEMENT

Projecting the performance of a roadway has historically been conducted treatment by treatment, by considering the "bump" in condition from a treatment and the expected life of the treatment. When the next treatment was applied, it was considered as independent of all the preceding treatments. Time has shown us that this independence is not necessarily true; long-term performance is the net effect of all the treatments and their timing. Considering a series of treatments enables an agency to think and act programmatically and develop "cradle to grave" economic analysis. It could also assist agencies in considering in situ situations where one or more treatments impacts lower pavement layers (for example, a series of surface seals resulting in stripping of lower hot-mix asphalt [HMA] layers).

Tasks: The research will include the following tasks:

1. Literature search on impact of series of treatments on performance of pavements. Perhaps a survey of agencies on common series and timing for various roadway categories.
2. Develop a strategy for evaluating treatments in series. Part of this strategy is to identify the types and amounts of data required to develop performance curves.
3. Collect sufficient data from state agencies to allow development of sample curves and validation of process.
4. Analyze data to develop example curves. Demonstrate the impact of the series versus one action at a time analysis.
5. Develop guidelines that allow an agency to develop performance curves for series of treatments if this analysis is demonstrated to be valuable.

Final Product:

This research will produce guidelines on how performance curves can be developed that incorporate a series of treatments. In addition, a final report will be developed that documents the approach, analysis, and findings of the research project.

III. RESEARCH OBJECTIVE

The objective of this research is to improve pavement performance modeling by considering the impact of the timing and treatments as a series rather than as independent activities.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $500,000
Estimated Project Duration: 36 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Method for Effectively Modeling Structural Condition

II. RESEARCH PROBLEM STATEMENT

Pavement performance models, to some extent, use only inputs from IRI and surface distress to predict future performance; however, it may be difficult to determine if surface distress identified through visual surveys is limited to the roadway surface (e.g., rutting or top-down cracking) or if it extends full-depth (e.g., bottom-up fatigue cracking). IRI and surface distress may not directly relate to measures of mechanistic features and therefore may not predict the present or future structural capacity. In addition, network-level (high-speed) structural condition data is limited in its availability and is a time consuming process. The availability of structural condition data on a network level would facilitate the development of improved performance models, which could be utilized in pavement preservation and treatment selection techniques. However, the actual benefits of collecting network-level structural condition data have not been fully quantified.

Tasks: The research will include the following tasks:

Phase I

1. Survey practitioners regarding network-level structural deflection testing.
2. Quantify cost/benefit ratio of network-level structural deflection testing.
3. Develop performance models, determine the applicability of use, and calibrate/validate to field conditions for the use of structural testing data.

Phase II

1. Validate/correlate high-speed deflection testing with traditional deflection testing devices.
2. Determine precision and bias statements for high-speed deflection testing.
3. Conduct pilot studies where high-speed deflection testing is used for quantifying pavement condition and estimating structural capacity needs.
4. Develop specifications and guidelines for use of high-speed deflection testing at the network-level.

Final Product:

The final product of the research is a set of guidelines for incorporating network-level structural testing into pavement management systems.

III. RESEARCH OBJECTIVE

There are three specific objectives for the research. First, the research will determine the cost/benefit ratio for network-wide structural testing to be incorporated into pavement management systems. The second research objective is to develop guidelines and performance models for incorporating structural testing into pavement management systems. The final objective is to validate high-speed structural testing equipment to accomplish network-level testing.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $350,000
Estimated Project Duration: 24 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Automation of Surface Texture Characteristics

II. RESEARCH PROBLEM STATEMENT

The use of automated (and semi-automated) pavement condition surveys have identified gaps in identifying and quantifying surface related characteristics such as bleeding, raveling, oxidation, splash/spray, friction, and noise. The need for identifying and quantifying these surface conditions for pavement preservation and pavement rehabilitation treatments/applications is vital. This study will identify surface characteristics that can be identified and quantified using existing high-speed data collection equipment, identify potential methodologies for quantifying distress, identify equipment and analysis gaps, develop specifications, and software and equipment modifications as necessary.

Tasks: The research will include the following tasks:

1. Survey manufacturers regarding data collection equipment's capabilities to measure and/or identify surface characteristics at traffic speeds. In addition, survey state highway agencies to determine data collection needs in relation to surface characteristics.
2. Identify analysis gaps and provide potential methodologies suited to identify/measure missing data sets.
3. Develop specifications, analysis procedures, software elements, and equipment modifications, as necessary, to address missing data sets.

Final Product:

The final product of the research is a set of guidelines, specifications and procedures for modify or implementing new pavement surface characteristics measuring capabilities at traffic speeds.

III. RESEARCH OBJECTIVE

There are two specific objectives for the research. First, the research will identify areas of improvement in enhancing or expanding automated pavement condition data collection capabilities. The second objective is developing specifications, guidelines, and methodologies for aiding the implementing of new data collection methods and analysis procedures.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $500,000
Estimated Project Duration: 36 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Identifying Strategies for Incorporating Emerging Technologies into Pavement Management Systems

II. RESEARCH PROBLEM STATEMENT

There are many changes that are impacting the use of pavement management in transportation agencies. For example, there is increased concern about the economic, environmental, and social impacts of pavement management decisions. For instance, pavement surface characteristics have become increasingly important to address user concerns regarding wet weather crashes, noise, and splash/spray. Similarly, methodologies are needed for incorporating sustainability factors into the project and treatment decision process. Finally, a methodology is desired for evaluating when new data collection technology should be incorporated into the pavement management process to further support agency decisions.

Tasks: The research will include the following tasks:

1. Identify the current state of the practice for incorporating emerging issues (e.g., sustainability) and technologies (e.g., new pavement friction testing equipment and data) into pavement management, including identification of critical performance criteria.
2. Develop best practices guidelines for modifying pavement management systems to incorporate emerging issues and/or technologies, including selecting applicable performance measures.
3. Develop tools (e.g., software) to support implementation of the developed guidelines.

Final Product:
The final products of the research are guidelines and software (or other support tools) to identify and evaluate the benefits of incorporating emerging technologies into a pavement management system.

III. RESEARCH OBJECTIVE

The objectives of this research include the development of guidelines for assisting pavement managers with incorporating emerging issues and related technologies into the pavement management systems, and the development of software or other decision-support tools that will help determine how new technologies can be most beneficially incorporated into pavement management.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $350,000
Estimated Project Duration: 24 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Quantifying the Cost of Pavement Use

II. RESEARCH PROBLEM STATEMENT

It is likely that "pay per use" strategies for funding transportation projects will have higher potential for use in the near future; however, this requires that agencies have the ability to quantify the cost of providing a sound, safe pavement for customer use so that rational pricing schemes can be developed.

Tasks: The research will include the following tasks:

1. Determine inputs needed to ascertain cost per use.
2. Develop an economic framework to derive the cost per use.
3. Develop guidelines for determining the cost per use.
4. Develop software based on process outlined in guidelines developed during task 3.

Final Product:
The research will result in guidelines and software for determining cost per use for funding transportation projects.

III. RESEARCH OBJECTIVE

There are three specific objectives for the research. First, the research will determine means to quantify the cost of providing pavement structures to the traveling public. The second objective is to develop written guidelines for using the means to quantify the cost per use of public transportation facilities. The final research objective is to develop a software program or package based on these guidelines.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $350,000
Estimated Project Duration: 24 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Develop Nondestructive Testing for Measurement of In-Place Material Properties

II. RESEARCH PROBLEM STATEMENT

Areas of low density in HMA pavements are susceptible to early failure due to stripping, cracking, and potholes. Low strength in portland cement concrete (PCC) pavements can result in fatigue cracking, poor load transfer, and spalling. The ability to quantify full lane width material properties, such as HMA density and PCC strength, would be beneficial for determining contractor pay incentives, quality assurance, and performance prediction models. Research using GPR to determine HMA density has been conducted; however, this process has not received wide-spread use in the United States. Similarly for PCC, the use of impact echo and spectral analysis of surface waves has been evaluated and utilized but has not received wide-spread use.

Tasks: The research will include the following tasks:

Phase I

1. Conduct a literature search of recent research related to the full lane width and high speed assessment of in situ material properties, specifically related to the upper wearing surface (e.g., HMA or PCC layer).
2. Identify limitations/benefits of developed testing equipment and procedures.
3. Determine the most effective and accurate methodology that can operate at highway speeds for determining the in situ material properties of a full lane width.

Phase II

1. Based on the findings of phase I, recommend methodologies for addressing equipment and/or analysis limitations.
2. Refine equipment and/or analysis techniques as needed.
3. Conduct case studies that demonstrate the ability (e.g., accuracy and repeatability) of equipment and/or analysis techniques modified in task 2.

Final Product:

Data collection equipment (operating at highway speeds) and analysis procedures/software for assessing the in situ material properties (full lane width) will result from this research.

III. RESEARCH OBJECTIVE

The objective for this research is to develop testing equipment and analysis procedures for measuring in situ material properties at highway speeds.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $800,000
Estimated Project Duration: 48 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Quantifying the Benefits of Pavement Research

II. RESEARCH PROBLEM STATEMENT

Several industries, such as the pharmaceutical industry, regularly invest a percentage of their sales in research and development activities. This practice is not widely practiced among transportation agencies; therefore, the consequences associated with the lack of funded research are not well understood.

Tasks: The research will include the following tasks:

1. Conduct a survey of SHAs in relation to pavement-related research conducted and implemented over the last 10 years, determine the investment costs for conducting the research (including implementation and training costs), and report benefits (e.g., extending pavement life or lowering life-cycle costs) due to the pavement research results.
2. Develop methodologies by which states can demonstrate the benefits of supporting higher investments for pavement research.
3. Prepare a report of findings and develop marketing tools that clearly illustrate the study findings.

Final Product:
The research will result in a methodology allowing a transportation agency to evaluate its research investments.

III. RESEARCH OBJECTIVE

The research will estimate the potential payoff afforded a transportation agency according to the level of research investment in pavement management.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $250,000
Estimated Project Duration: 12 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Develop Default Models for Low-Volume Roads

II. RESEARCH PROBLEM STATEMENT

Many pavement management systems were not developed using data from low-volume roadways. Dependent on the demographics of an individual state, lack of data for low-volume roads may be related to challenges due to collecting data in remote areas, minimal traffic loadings that would typically require standard preservation/rehabilitation treatments (e.g., chip sealed roadway that will only receive future chip seals), or possibly the lack of needed data (e.g., construction history) due to roadway transfer from local agencies. In addition, the Mechanistic-Empirical Pavement Design Guide (MEPDG), due to lack of reliable data concerning low-volume pavement design and performance, specifically excluded the design of low-volume roadways. However, pavement performance and treatment selection on low-volume roadways can be significantly different than that of higher volume roadways.

Tasks: The research will include the following tasks:

1. Survey local and state highway agencies regarding data for low-volume roads, specifically related for use in pavement design, performance predication, and selection of appropriate preservation and rehabilitation treatments.
2. Identify available models for predicting pavement performance on low-volume roads. If necessary, provide recommendations to modify, or if unavailable, develop pavement performance prediction models for low-volume roadways.
3. Identify available pavement design procedures for low-volume roadways (including those developed abroad). If necessary, provide recommendations to modify, or if unavailable, develop pavement design procedures/practices (for consideration in DARWin-ME) for low-volume roadways.
4. Develop guidelines for including performance prediction models and pavement design practices into pavement management and pavement design practices and procedures.

Final Product:
The final product of the research is pavement performance models and design procedures for low-volume roadways.

III. RESEARCH OBJECTIVE

There are three specific objectives for the research. First, the research will determine the availability of pavement management data in relation to low-volume roadways. The second objective is to identify, modify or develop practices, procedures, and performance prediction models into pavement management systems. The final objective is to identify, modify, or develop pavement design procedures for low-volume roadways.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $350,000
Estimated Project Duration: 24 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Impact of Climate Change on Performance Prediction

II. RESEARCH PROBLEM STATEMENT

Little is known about the impact of climate change (e.g., rising temperatures and sea levels, increased storm frequency) on the future performance of highway pavements. In recent years, pavement related impacts of climate changes, such as Hurricane Katrina, flooding of the Red River, and the rising temperatures found in many regions of the United States and abroad, are needed. Specifically, information is needed on how climate change may affect the ability to predict pavement performance.

Tasks: The research will include the following tasks:

1. Conduct a literature search and review investigating links between pavement performance and climate change impacts.
2. Identify potential performance models taking into account climate change.
3. Evaluate and revise existing models and develop new models addressing needs identified in the literature as not being presently accounted for.
4. Develop guidelines for incorporating the models vetted in task 3 into pavement management.

Final Product:
The final product of the research is a set of guidelines for incorporating models linking pavement performance and climate change impacts.

III. RESEARCH OBJECTIVE

There are three specific objectives for the research. First, the research will determine the current state of the practice regarding pavement performance relative to climate change. The second objective is to develop performance models to address climate change impacts on pavement performance. The final research objective is to develop guidelines that transportation agencies can use to implement pavement performance models based on climate change impacts.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $350,000
Estimated Project Duration: 24 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Development and Integration of Wireless Sensors with PMS

II. RESEARCH PROBLEM STATEMENT

Technology for the monitoring of pavement condition does not appear to have kept pace with other technological improvements over the past several years. Research and development are underway to advance the monitoring of pavement condition to provide better relationships among distresses, performance, traffic, maintenance, and other significant variables. Presently, two approaches are typically taken to monitor the condition of pavements: manual distress surveys and automated condition surveys using specially equipped vehicles (e.g., imaging technology for distress survey and transverse profiling for the wheel path rutting). However, these monitoring approaches remain rather more reactive than proactive in terms of detecting damage, since they merely record the distress that has already appeared. Other testing approaches are also used (e.g. deflection testing); however, most of these methods either require significant personnel time or the use of costly equipment. Thus, they can only be used cost-effectively on a periodic and/or localized basis. Currently, pavement instrumentation for condition monitoring is done on a localized and short-term basis. The current technology does not allow for continuous long-term monitoring, and the deployment of existing systems on a network level remains unfeasible due to cost, unease of installation, and data collection techniques. Long-term monitoring of mechanical loading for pavement structures could reduce maintenance cost, improve longevity, enhance safety, and advance research in pavement design and construction operation.

There is ongoing research to develop a self-contained smart pavement monitoring system consisting of wireless integrated circuit sensor that consumes less than one microwatt of power and interfaces directly with and draws its operational power from a piezoelectric transducer. By combining floating-gate transistors with piezoelectric transducer, the sensor is able to achieve operational limits wirelessly. The miniaturized sensor will enable continuous battery-less monitoring of integrity of pavement structures over long periods (i.e., detect damage, monitor loading history, and predict fatigue life of the monitoring pavement). The envisioned system would consist of a network of low cost sensors distributed along the pavement during new construction, reconstruction, or resurfacing of both asphalt and concrete pavements. Each sensor node would be self-powered and capable of continuously monitoring and storing the dynamic strain levels in host pavement structure. The data from all the sensors would be periodically uploaded wirelessly to a central database, either through radio-frequency transmission using a radio-frequency reader either manually operated or mounted on a moving vehicle. It is possible that this update can be accomplished during the pavement management condition surveys by adding receivers to the same automated data collection vehicle enabling the collection and population of the sensor data to the pavement management system in a timely and consistent manner. The data will help facilitate a more effective pavement maintenance and rehabilitation/preservation schedule.

Additional research is needed to optimize data collection and storage with these types of sensors. Efforts are needed to integrate this sort of data within existing agency databases in order to make optimal use of the data available.

Tasks: The research will include the following tasks:

1. Determine hardware and software needs for the pavement network system data collection, storage and retrieval, etc.
2. Evaluate data collection alternatives (i.e., the storage node placement for data collection and retrieval, reader driving over pavement, etc.).
3. Evaluate data retrieval alternatives and method of transmitting data to a central place for archiving and analysis.
4. Utilize wireless sensor system in the field and evaluate pavement network system data collection, storage, retrieval, and transferring processing operation.

Final Product:
The research products will be reports that document the test results, guidelines for usage and integration of the sensors, and prototype sensors with information to make them commercially available.

III. RESEARCH OBJECTIVE

The overall objective of the study is to utilize a wireless, self-powered, and low-cost integrated network sensor system for long-term mentoring pavement condition. The system enables continuous monitoring and stores the dynamic strain levels in host pavement structure. The data from the sensors would be periodically uploaded, using a radio-frequency reader either manually operated or mounted on a moving vehicle, wirelessly to a central database to help facilitate a more effective pavement maintenance and rehabilitation/preservation schedule.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $500,000
Estimated Project Duration: 36 months

RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Use of Aerial Images for Distress Analysis

II. RESEARCH PROBLEM STATEMENT

Nationwide, the current method of collecting pavement distress involves either driving or walking an extensive pavement network. Data collection and analysis can range from manual, semi-automated to fully automated procedures. For a SHA using semi-automated or automated data collection equipment, the distance traveled during data collection can easily be double or triple the number of miles of data collection (due to dead heading and mobilization of equipment and staff). In addition, depending on weather and traffic conditions, the time to collect pavement condition data can be restricted such that it becomes challenging to collect data in a reasonable period of time. The use of satellite images for quantifying pavement distress may provide another source of data collection that can be quickly collected, drastically minimize or element the need to drive to the testing locations, and minimize safety issues by removing staff from the data collection process.

Tasks: The research will include the following tasks:

Phase I

1. Determine the adequacy of current technology in use of aerial images for pavement condition surveys.
2. Identify gaps in data collection and analysis, determine what needs to be developed to further the application of this technology, and determine if declassification of images is needed in order for this process to become a reality.

Phase II

1. Determine which technologies have possibilities for use in the pavement condition survey.
2. Develop, as needed, technologies and necessary software for using aerial images for data collection and analysis.
3. Develop guidelines on use of aerial images for pavement condition surveys.

Final Product:
The product of this research will be software and guidelines for using aerial images for pavement condition assessment.

III. RESEARCH OBJECTIVE

Identify what improvements could be made to existing imagery or would need to be developed to make the use of aerial images for pavement condition assessment possibility. In addition, determine if satellite imagery can provide data that is cost effective and of sufficient quality to meet the needs of (or contribute to) a pavement management system.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Estimated Budget: $800,000
Estimated Project Duration: 48 months