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PAVEMENT MANAGEMENT ROADMAP

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16. Abstract The FHWA's update to its <i>Pavement Management Roadmap</i> helps to identify the steps that will address current gaps in pavement management and to establish research initiatives and priorities. Initial gaps were identified based on a literature review, project team knowledge, and a satisfaction survey of Federal, State, and local pavement management practitioners (authorized under Office of Management and Budget control number 2125-0628). They were grouped according to four themes: Theme 1 – Data, Theme 2 – Pavement Management Analysis Tools and Other Applications, Theme 3 – Workforce and Organization Issues, and Theme 4 - Technological Advancements – New Tools, Methodologies, and Technology. The <i>Roadmap</i> was derived from a series of virtual stakeholder workshops in which representatives from State and local agencies, academia, private industry, and the FHWA met to discuss and prioritize suggestions for enhancing current practices. The <i>Roadmap</i> contains 72 action items (46 short-term and 26 long-term) in 15 improvement areas across the four themes. The results can be used to determine new research, development, and technology transfer opportunities.					
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TABLE OF CONTENTS

1.0 Introduction.....	1
Background.....	1
Gap Assessment.....	2
Theme Areas.....	4
Document Organization.....	7
2.0 Gap Assessment.....	8
Introduction.....	8
Theme 1: Pavement Management Data.....	8
Topic Area 1-1: Data.....	10
Topic Area 1-2: Data Quality.....	11
Theme 2: Pavement Management Analysis Tools and Other Applications.....	12
Topic Area 2-1: Modeling.....	14
Topic Area 2-2: Support for TPM and Transportation Asset Management (TAM).....	15
Topic Area 2-3: Project Selection.....	15
Topic Area 2-4: Other Applications for Pavement Management Data and Analysis.....	16
Theme 3: Workforce and Organizational Issues.....	16
Topic Area 3-1: People.....	17
Topic Area 3-2: Pavement Management Funding Risks.....	18
Topic Area 3-3: Integration into Existing Systems and Processes.....	18
Topic Area 3-4: Data and Technology.....	19
Topic Area 3-5: Communication and Outreach.....	19
Theme 4: Technological Advancements – New Tools, Methodologies, and Technology.....	20
Topic Area 4-1: Advancements in Automated Pavement Data Collection Technologies.....	21
Topic Area 4-2: Technologies to Assess Pavement Subsurface Characteristics and Structural Properties.....	22
Topic Area 4-3: Emerging Data Collection Technologies and Methodologies for Assessing Pavement Distresses and Other Surface Characteristics.....	22
Topic Area 4-4: Improving Pavement Management Data and Analysis Tools.....	22
Topic Area 4-5: Next Generation Performance Measures.....	23

Establishing Priorities	23
3.0 10-Year Pavement Management Roadmap	24
Long-Term Vision for Pavement Management	24
Pavement Management Vision	24
Improvement Areas.....	25
Theme 1: Data.....	27
Theme 2: Pavement Management Analysis Tools and Other Applications	27
Theme 3: Workforce and Organizational Issues.....	27
Theme 4: Technological Advancements – New Tools, Methodologies, and Technology	27
Suggested Action Items by Theme	29
Theme 1: Data.....	30
Theme 2: Pavement Management Analysis Tools and Other Applications	32
Theme 3: Workforce and Organizational Issues.....	34
Theme 4: Technological Advancements – New Tools, Methodologies, and Technology	36
4.0 Pavement Management Roadmap Implementation	38
Roadmap Highlights	38
Implementation Approach	39
Federal Highway Administration (FHWA)	39
National Cooperative Highway Research Program (NCHRP)	41
American Association of State Highway Transportation Officials (AASHTO).....	41
Pooled Fund Studies	41
Transportation Research Board (TRB)	42
Private Industry	42
Academia	43
APPENDIX A – RELEVANT ACRONYMS & GLOSSARY	A-1
APPENDIX B – PRIORITIZED ACTION ITEMS	B-1
APPENDIX C – SUGGESTED ACTION ITEMS.....	C-1

1.0 INTRODUCTION

BACKGROUND

In 2010, the Federal Highway Administration (FHWA) published its first *Pavement Management Roadmap*.¹ The document was developed through a collaborative process involving stakeholders from Federal, State, and local governmental agencies; private industry; and academia. The *Roadmap* established a 10-year vision for pavement management and outlined 47 potential short- and long-term research and implementation activities, with more than \$14.5 million in associated funding requests. Following the publication of the *Roadmap*, the FHWA developed a marketing plan and websites to track research activities² and to promote the document among different stakeholder groups.³

In the years since the first *Roadmap* was released, many of the suggestions have been addressed to varying degrees of completion through research initiatives, deployment documents, technical assistance programs, and technology transfer activities. In the data areas, the FHWA published several resources related to improving data quality to support pavement management and supported the implementation of these resources through workshops, webinars, and other outreach efforts. The FHWA also sponsored a series of Pavement Management Peer Exchanges to provide opportunities for practitioners to share practices and discuss common issues. Research initiatives through the FHWA's Office of Research, Development, and Technology; the National Cooperative Highway Research Program (NCHRP); Pooled Fund Studies; and other agencies also helped advance the state of practice. These efforts addressed methods for analyzing pavement conditions using automated technology, evaluating pavement structural condition, using preservation treatments to reduce pavement life cycle costs, and many other suggestions.

Today's pavement management practices reflect the advancements that have been made since 2010 as well as the current environment in which they operate. A Gap Assessment conducted as part of the development of this *Roadmap* evaluated the changes that have taken place along with the current research, innovation, and technology transfer requests from pavement management practitioners. The current suggestions for action are based on changes in legislation, technology, and agency workforces. For instance, since the development of the 2010 *Roadmap* the pavement management community has been experiencing a transition from manual to automated technology to collect pavement condition information. Also, there has been an increased focus on pavement management due to the emergence of the asset management and transportation performance management (TPM) areas that resulted from the Moving Ahead for Progress in the 21st Century Act (MAP-21) and the Fixing America's Surface Transportation (FAST) Act. These laws required the establishment of new national pavement

¹ <https://www.fhwa.dot.gov/pavement/management/roadmap/>

² https://www.fhwa.dot.gov/pavement/management/roadmap/act_ps.cfm

³ https://www.fhwa.dot.gov/pavement/management/roadmap/act_market.cfm

performance measures (codified at 23 CFR part 490) and required State Departments of Transportation (DOTs) to develop risk-based Transportation Asset Management Plans (TAMPs) for pavements and bridges on the National Highway System (NHS) (23 U.S.C. 119(e)). The laws also placed increased importance on pavement management to set short- and long-term performance targets, to define a State of Good Repair (SOGR), to conduct life cycle planning (LCP), and to identify 10-year investment strategies that are consistent with their TAMP. As a result, there is increased awareness for the importance of improving pavement performance models, streamlining data collection efforts, addressing data quality issues, aligning project selection activities with pavement management project suggestions, and improving tools to support network-level life cycle planning.

Within this context, the FHWA initiated the development of this *Roadmap* to reflect current capabilities, practices, and the resulting gaps. This update presents a 10-year pavement management strategy for the FHWA and other transportation agencies to drive research, transformative innovation development, and technology transfer activities that will continue to improve pavement management practices.

GAP ASSESSMENT

Several sources of information were used to identify pavement management practice gaps, including those listed below.

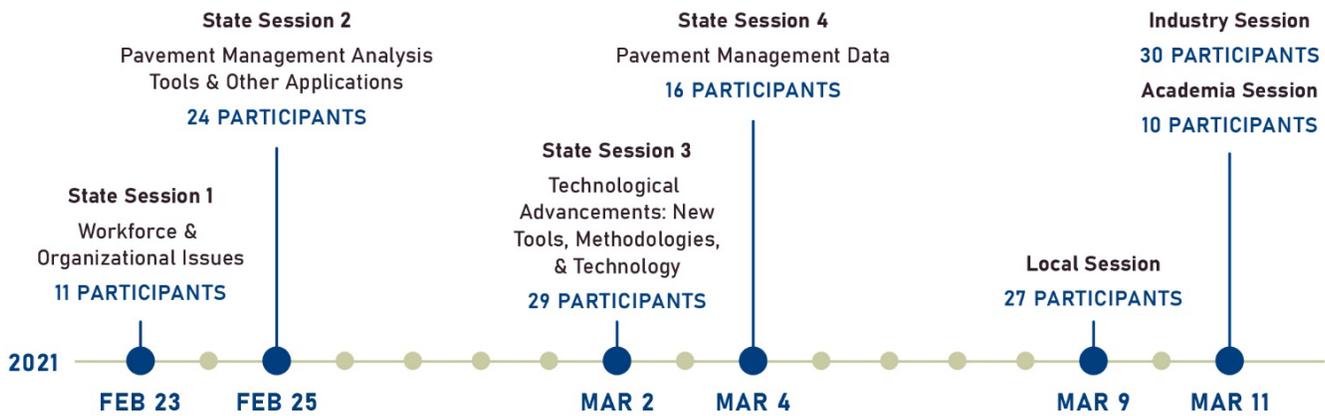
- A benchmark survey was conducted. An electronic survey was distributed to pavement management engineers at each of the 52 State DOTs (including Puerto Rico and Washington D.C.) and representatives from 25 local and regional transportation agencies in September 2020⁴. A total of 61 responses were received, with 53 responses coming from State DOT employees representing all 52 State DOTs and 8 coming from local or regional transportation agencies. The survey provided insight on agency satisfaction with existing pavement management resources, including their ability to support pavement management practices.
- A literature review was conducted to identify ongoing and completed research and other activities impacting pavement management since the 2010 *Pavement Management Roadmap* was published.

Pavement Management Roadmap Objective

Present a 10-year strategy that can be used by the FHWA and other transportation agencies to guide continued identification of research needs, transformative innovation development, and technology transfer opportunities that will continue to improve pavement management practices.

⁴ Authorized under Office of Management and Budget (OMB) Control Number 2125-0628.

- Virtual stakeholder outreach activities were conducted. These web-based sessions were designed to identify, assess, and prioritize gaps that hinder the full utilization of pavement management principles and practices. A total of 147 Federal, State, local, industry, and academic participants were involved in the meetings, with some State DOT participants attending several sessions.
 - February 23, 2021: State Session 1: Workforce and Organizational Issues – 11 participants.
 - February 25, 2021: State Session 2: Pavement Management Analysis Tools and Other Applications – 24 participants.
 - March 2, 2021: State Session 3: Technological Advancements – New Tools, Methodologies, and Technology – 29 participants.
 - March 4, 2021: State Session 4: Pavement Management Data – 16 participants.
 - March 9, 2021: Local Session – 27 participants.
 - March 11, 2021: Industry Session – 30 participants.
 - March 11, 2021: Academia Session – 10 participants.



Following the stakeholder outreach sessions, participants were invited to a follow-up meeting to prioritize the gaps and suggested strategies. The prioritization session, which was held on April 22, 2021 with 54 participants, provided insights into the types of research, deployment, and technology transfer activities that are reflected in this *Pavement Management Roadmap*.

THEME AREAS

The *2010 Pavement Management Roadmap* was organized around these themes:

- Theme 1: Use of Existing Tools and Technology included suggestions for technology and tools that can support traditional pavement management applications. In general, this theme includes technology and tools that are available but would benefit from additional review, analysis, dissemination, and/or updating prior to their use.
- Theme 2: Institutional and Organizational Issues included action statements about workforce development, communication, contracting, and organizational structure. The suggestions in this area address the impact pavement management has on funding and how to determine, promote, and effectively communicate the use and benefits of pavement management.
- Theme 3: The Broad Role of Pavement Management went beyond the standard functions of pavement management and includes such areas as design, the impact of increasing load limits on performance, and asset management.
- Theme 4: New Tools, Methodologies, and Technology identifies research and development opportunities that could lead to new tools, methods, and technology to support pavement management. In general, action item statements in this theme address concepts that are not readily available and would involve a higher level of research, analysis, and development prior to implementation.

Based on the information gleaned during the Gap Assessment, for this update the themes were modified slightly to better reflect the present environment and the current desires of the pavement management community.

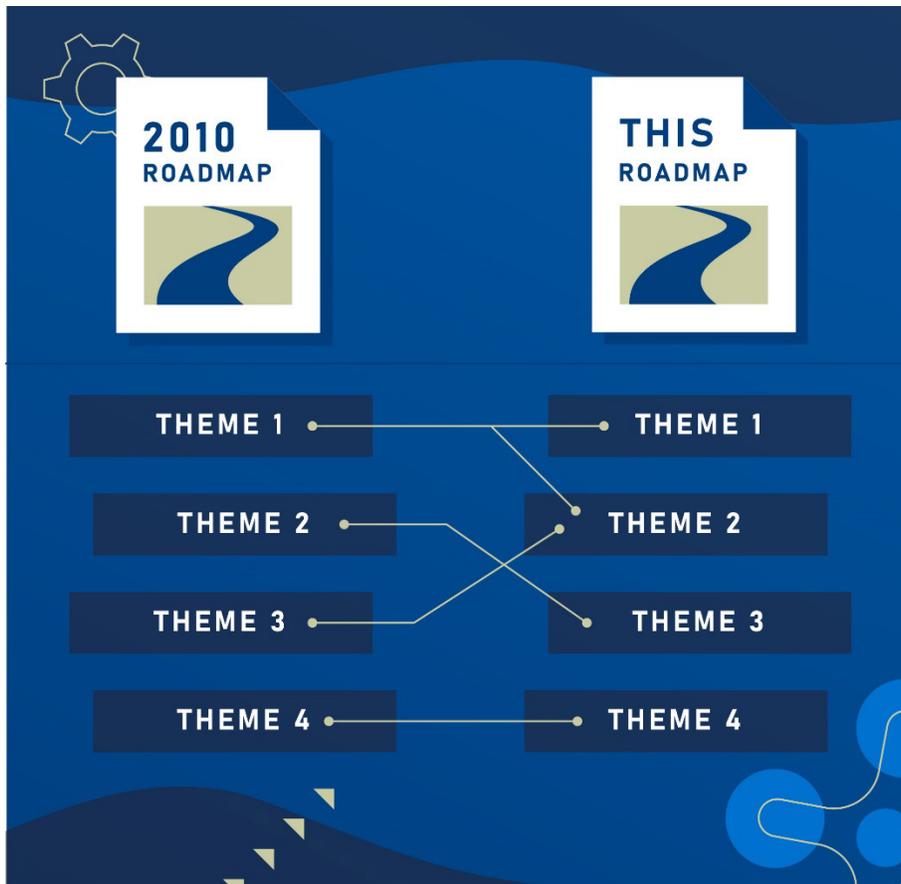
- **Theme 1: Pavement Management Data** – This theme concentrates on pavement management data gaps, including collection, quality control, acceptance, contracting, storage, and management. The gap assessment results and the *Roadmap* suggestions in this theme are organized into the two topics listed below.
 - Topic 1-1: Data.
 - Topic 1-2: Data quality.
- **Theme 2: Pavement Management Analysis Tools and Other Applications** – This theme builds from theme 3 in the prior *Roadmap* (The Broad Role of Pavement Management) but also includes pavement performance modeling and the emerging area of pavement performance measurement. The gap assessment results and the *Roadmap* suggestions in this theme are organized into these four topics:
 - Topic 2-1: Modeling.
 - Topic 2-2: Support for Transportation Performance Management (TPM) and Transportation Asset Management (TAM).
 - Topic 2-3: Project selection.
 - Topic 2-4: Other applications of pavement management data.



- **Theme 3: Workforce and Organizational Issues** – This theme is similar to theme 2 in the 2010 *Roadmap* (Institutional and Workforce Issues) with an increased emphasis on communication, training, and workforce development issues. The gap assessment results and the *Roadmap* suggestions in this theme are organized into the following four topics:
 - Topic 3-1: People.
 - Topic 3-2: Pavement management funding risks.
 - Topic 3-3: Data and technology.
 - Topic 3-4: Communication and outreach.

- **Theme 4: Technological Advancements – New Tools, Methodologies, and Technology** – As in the previous *Roadmap*, this theme focuses on future developments that will impact pavement management over the next 10 years. The gap assessment results and the *Roadmap* suggestions in this theme are organized into the five topics listed below.
 - Topic 4-1: Advancements in automated pavement distress data collection interpretation technologies.
 - Topic 4-2: Technologies to assess pavement subsurface characteristics and structural properties.
 - Topic 4-3: Emerging data collection technologies and methodologies for assessing pavement distresses and other surface characteristics.
 - Topic 4-4: Improving pavement management data and analysis tools.
 - Topic 4-5: Next-generation performance measures.

The relationship between the themes in the 2010 and current *Roadmaps* are reflected in the following graphic.



The *Pavement Management Roadmap* is organized into four sections and three appendices.

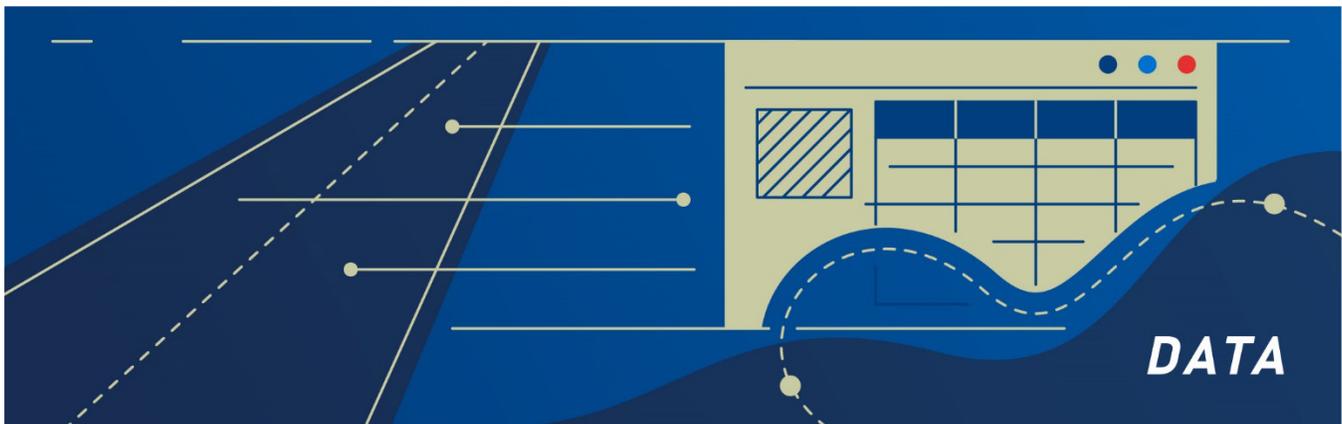
- Section 1, Introduction, describes the approach used to develop the *Roadmap*.
- Section 2, Gap Assessment, summarizes information and insights gained through the gap assessment.
- Section 3, 10-Year *Pavement Management Roadmap*, presents prioritized suggestions for research, development, and technology transfer opportunities over the next 10 years.
- Section 4, *Roadmap* Implementation, presents ideas for advancing the activities outlined.
- Appendix A includes a list of acronyms used in the document and a glossary of terms.
- Appendix B presents the results from the final Stakeholder Outreach session that addressed priorities.
- Appendix C includes suggested Action Item Statements describing potential actions to address existing gaps and their associated costs.

In addition to this report, an Executive Summary was published separately. The Executive Summary highlights key findings and suggested short- and long-term activities.

2.0 GAP ASSESSMENT

INTRODUCTION

The results from the gap assessment were used to evaluate changes in practice since the publication of the 2010 *Roadmap*. For each theme, a short summary describing current practice is provided, followed by gaps that limit agencies' ability to fully realize the benefits associated with pavement management implementation. The gaps are primarily based on information obtained from the baseline survey, the literature review, or the stakeholder outreach sessions.



THEME 1: PAVEMENT MANAGEMENT DATA

Data collection techniques and equipment have changed over the last decade, taking advantage of technology to efficiently collect and accurately characterize pavement condition data. This data serves as the basis for reliably predicting network pavement conditions, identifying rehabilitation or preservation treatment types and timing, and supporting the increasing capabilities associated with asset management and TPM. The baseline survey conducted for this project indicates that State agencies continue to rely on rutting, ride, and surface condition to support their pavement management activities while local agencies rely less on ride and more on surface condition. Federal reporting requirements for pavements on the National Highway System have introduced new standardized performance measures (23 CFR part 490, subpart C) that may be used in addition to, or as a replacement for, legacy performance measures.

The technology used in automated pavement condition assessment enable pavement condition surveys to shift from time-intensive manual procedures to traffic-speed automated collection processes that efficiently combine the use of sensors and digital images. Although this equipment has improved measurement accuracy, shortened the time for data collection, and improved rating crew safety, the baseline survey found differences among agencies in how the data are processed and used. For instance,

distress interpretation procedures from the digital images collected in the field can vary widely from one agency to another. The costs associated with the use of this technology are high, making data collection expensive. Strategies to combine data collection activities across the agency to reduce redundancy and to maximize the benefit from these expenditures show promise.

In recent years the FHWA has issued regulations (23 CFR part 490, subpart C) for standardized approaches to collecting and reporting the International Ride Index (IRI), rutting, faulting, and cracking percentages on the NHS. However, the procedures for collecting and processing NHS pavement condition data are not consistently used for non-NHS or locally managed roads. The lack of consistently used procedures for collecting and processing pavement condition information for non-NHS roads makes it difficult to compare performance across agencies and results in automated equipment vendors interpreting data using multiple algorithms.

Changes in data collection equipment technology can create compatibility issues with historical data. These issues may be addressed through the development of correlations between data sets. Compatibility issues can also lead to inconsistencies in pavement deterioration trends that impact future projections. Changes in technology also have provided an opportunity to collect data that could not be easily collected in the past. Examples include ground penetrating radar (GPR), traffic speed deflection devices (TSDD), unmanned aircraft systems (UAS), and crowdsourced data. These techniques might supplement or even replace more traditional ways to obtain pavement management data. Practitioners face the challenge of deciding whether the data collection methods being used today are adequate to meet their demands or whether changes are warranted.

Regardless of the method used to collect the data, the reasonableness and reliability of the pavement management project suggestions are directly linked to the quality of the data being used. The review for data quality may include comments related to completeness, correctness, validity, consistency, timeliness, and accuracy. The task of 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, the agency would also generally be responsible for ensuring data quality.

Managing data quality typically includes activities at three stages: prior to the start of the surveys, while the data collection is being conducted, and upon receipt of the data. At present there are limited programs available for equipment calibration and operator certification. Equipment calibration for some types of equipment, such as falling weight deflectometers (FWDs), can be performed at regional calibration centers, but these are not used widely for other types of equipment. During the production period when surveys are conducted, many agencies perform periodic “checks” on the data by reinspecting representative sites or by checking results at blind control sites that are unknown to the data collection vendor. Once the surveys are complete, acceptance testing to check for obvious errors or data inconsistencies are often conducted by the agency before entering the data into the pavement management system. In recent years, State DOTs have developed Data Quality Management Programs (DQMP) to ensure the level of quality in data collection deliverables and processes, as required in 23 CFR 490.319.

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 can 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. Although the FHWA has issued guidelines to help ensure the quality of this data⁵, practitioners in the stakeholder outreach sessions noted the variability associated with distress surveys makes results difficult to compare.

The availability of certain types of data for pavement management purposes was also reported to pose challenges for many DOTs during the stakeholder outreach sessions. For example, pavement management databases typically do not contain construction information, such as pavement thickness, material, treatment type, and completion date. The use of GPR shows some promise for recording layer thicknesses on a network basis as do 3-D as-builts from Building Information Modeling (BIM) and Civil Integrated Management (CIM).

Topic Area 1-1: Data

Practice gaps identified by stakeholders related to collection methods, criteria, contracting, storage, and management are summarized below.



- Determining the appropriate level of data accuracy and precision to support pavement management.
- Selecting the suitable level of data collection extent and frequency to support pavement management.
- Identifying the types of data desired to support pavement management decisions.
- Addressing challenges with transitions in data collection methodology (e.g., changes in process, equipment, or vendor) to facilitate historical comparisons.
- Determining the best approach for the agency to manage large amounts of data over time.
- Improving the accuracy and use of pavement history data.
- Piggybacking pavement management data collection with other data collection activities within the agency in a meaningful and economical way.
- Improving the effectiveness of data collection contracting.
- Reducing the time between conducting pavement condition surveys and the availability of results.
- Improving data consistency.

⁵ <https://www.fhwa.dot.gov/pavement/management/pubs/dqmp.pdf>

- Applying existing data collection methods, including the application of automated data collection, to low-speed roadways such as local streets.
- Reconciling manually collected data with data collected using automated equipment.
- Removing contract provisions that limit data collection contracts to 1 year.
- Dealing with discrepancies between the level of detail in the data collected and the information desired to support decision making.
- Locating geospatial positions accurately.
- Expanding collection activities beyond pavement surface distress to include items such as signs, pavement markings, and curb cuts for accessibility.
- Reporting pavement maintenance information consistently with pavement management segments.
- Connecting data from a maintenance management system to pavement management.

Topic Area 1-2: Data Quality

Practice gaps identified by stakeholders related to data quality standards, specifications, quality control, and acceptance testing are summarized below.



- Automating data quality checks to speed-up and simplify the process of identifying problems with the data.
- Understanding the risks and benefits associated with different levels of data quality so that informed decisions can be made on the amount of data needed for national- and State-level reporting or for use in modeling pavement performance.
- Having methodologies and tools available for verifying cracking types and amounts, transverse profile, and faulting values obtained from automated data collection activities.
- Collecting reliable data on PCC and composite pavements.
- Applying consistent procedures to certify data collection equipment and operators.
- Checking automated equipment for quality issues in real time (e.g., such as noting the presence of a failing sensor).
- Understanding the statistics used in developing a Data Quality Management Program and the impacts acceptance criteria can have on data collection practices.
- Quantifying ground truth values for determining the accuracy of longitudinal profile, transverse profile, cracking, distress, and texture data collected using different approaches.
- Establishing reasonable acceptance criteria (for timeliness, completeness, and quality) for data collected either internally or by contract.

- Offering training and technical assistance on equipment calibration and certification, statistics, pavement data quality control measures, certification of pavement data collection personnel, error resolution, and data checking processes.
- Understanding the importance of data quality, and the evaluation criteria used to assess it, among all stakeholders, including agency management and other decision makers.
- Skipping data quality checking due to demands on available resources.
- Establishing a data quality management program for new and emerging technology.
- Managing transitions in reference systems.



THEME 2: PAVEMENT MANAGEMENT ANALYSIS TOOLS AND OTHER APPLICATIONS

The 2010 *Pavement Management Roadmap* recognized pavement management's role was broadening beyond the traditional activities associated with reporting conditions and prioritizing capital program investments. The vision included in the *Roadmap* foresaw pavement management operating within an asset management framework, which was reinforced in 2012 under MAP-21 and was later continued under subsequent legislation. The increased use of asset management practices has led to considerable emphasis on the use of pavement management systems and practices by State and local transportation agencies as well as metropolitan and regional planning organizations (MPOs and RPOs).

Pavement management systems are important tools for identifying and evaluating life cycle strategies and planning 10-year investment strategies. The use of a pavement management analysis for these purposes prompted stakeholders to express interest in improving current approaches for pavement performance modeling and treatment rule development, especially those related to the performance of preservation treatments. The consideration of current and future risks in performance models, including future environmental risks, also emerged as a gap. The baseline survey also indicates that few agencies have documentation on how the models were initially developed and modified over the years. This could lead to challenges during staff transitions as pavement management practitioners are promoted or retire.

The baseline survey also indicated that pavement management information is being used to support broader agency practices, such as pavement design and transportation planning, programming, and project scoping. Some DOTs have also used pavement management data to inform the development of district work plans. These activities may rely on the efforts of pavement management champions rather than agency processes that have formally integrated pavement management information into agency decisions. The successful transition of pavement management into these areas benefits from a level of confidence in the systems and their outputs.

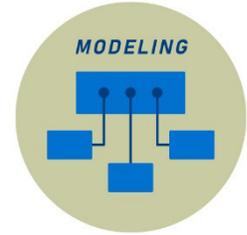
The use of pavement management information to support TPM and asset management has also generated interest in determining how the data can be used for performance target setting and risk management. The stakeholder outreach activities identified challenges associated with agencies' efforts to reconcile historical agency performance measures with the Federal performance measures. The baseline survey identified interest among practitioners in the identification of leading rather than lagging performance measures (beyond those required under 23 CFR part 490, subpart C for pavements) that would enable agencies to be more proactive in addressing planned investments. Financial or life-cycle measures that allow investments in different asset classes to be compared on an equal basis are examples of the types of leading measures that would be of interest. As environmental threats (e.g., climate change) and societal impacts (e.g., social justice) become more important to decisions about how the network is managed, pavement management practitioners responding to the survey indicated it would be helpful to find ways that these factors can be accounted for in the analysis of optimal projects and treatments.

In addition to performance target setting and risk management, pavement management analyses serve as the basis for LCP and investment planning as part of the development of a TAMP. The ability to forecast future conditions is key to these types of analyses. Practitioners expressed concern with their ability to predict future conditions due to the lack of reliable pavement history, variability in condition data, and uncertainty in expected budget levels. LCP serves as the foundation for investment planning and practitioners also questioned whether they had sufficient knowledge to support a robust LCP analysis.

To address the broad demands for pavement management data and information, pavement managers benefit from being flexible in how they react to unforeseen requests so they can assist with problem solving. For example, pavement management data could be used to evaluate the long-term impacts of changes to design or construction practices. The ability to respond to these types of inquiries relies on quality data that addresses a broad range of demands within the agency. It also benefits from pavement management staff with the skills necessary to conduct these types of analyses to realize the full potential of a pavement management system.

Topic Area 2-1: Modeling

Practice gaps identified by stakeholders related to pavement performance modeling are summarized below.



- Understanding when pavement performance models should be updated.
- Knowing how to account for data variability in developing or updating pavement performance models.
- Incorporating system performance, climate change (both current and future impacts), risk, and resiliency in pavement management modeling and analysis.
- Using the system to develop strategies that allow the impact on life cycle costs to be considered in investment planning.
- Considering risk management, carbon footprint, and life cycle cost reductions in the project prioritization analysis within the pavement management system.
- Modeling for the next generation of pavement performance measures, such as financial and life cycle planning performance measures.
- Considering the long-term impact on pavement performance of multi-objective project selection.
- Incorporating pavement maintenance and preservation in pavement management models.
- Having information on pavement condition immediately prior to receiving a treatment so that differences in pre-treatment condition can be incorporated into models.
- Documenting pavement performance models and treatment rules.
- Deciding when and how to invest in new software tools.
- Addressing differences in pavement costs versus project costs in the PMS.
- Incorporating other useful data in the pavement management system using new tools and approaches (e.g., machine learning), including:
 - New pavement sensor data.
 - Safety metrics (e.g., friction and curvature).
 - Network-level structural data (e.g., TSDD and pavement layer data).
 - Sustainability metrics.
 - Drainage conditions and effectiveness.
 - Construction materials and quality.
 - The impact of past damage (from events such as floods and fires) on future pavement performance.

Topic Area 2-2: Support for TPM and Transportation Asset Management (TAM)

Practice gaps identified by stakeholders related to the ability of a pavement management system to support TPM and TAM activities are summarized below.



- Reconciling agency legacy and Federal pavement performance measures.
- Explaining differences associated with the Federal and agency (i.e., legacy) pavement cracking procedures.
- Stabilizing performance indices after changes in data collection protocols or vendors.
- Using leading performance measures in pavement management.
- Setting effective performance targets using historical pavement data, models, and budgets.
- Identifying suitable pavement performance measures for urban environments where roughness measures are not meaningful.
- Having sufficient knowledge on how to use a pavement management system to support activities such as setting performance targets, establishing a desired state of good repair, developing life cycle strategies, informing cross-asset trade-offs, and suggesting 10-year investment strategies.
- Linking the PMS with bridge management systems and TPM.
- Aligning the TAMP with other planning and programming activities.
- Using the PMS to minimize emergency repair damage.

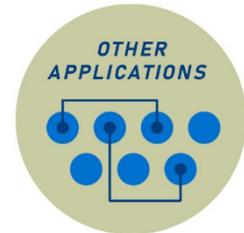
Topic Area 2-3: Project Selection

Practice gaps identified by stakeholders related to factors impacting project selection are summarized below.



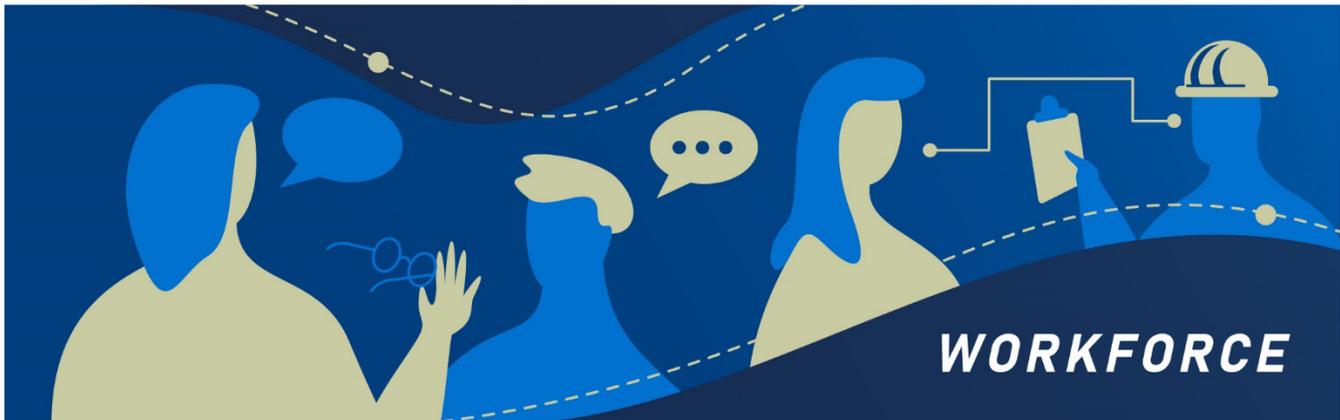
- Addressing ongoing differences between pavement management suggestions and projects selected for funding.
- Effectively communicating pavement management results in a meaningful way to both internal and external stakeholders.
- Considering factors such as risk, non-pavement criteria (e.g., bike and pedestrian features), and social impacts in project selection processes.
- Addressing the amount of time that occurs between project identification, project funding, construction, and documentation of condition improvements.
- Addressing the analytical challenges associated with big-data sets.

Topic Area 2-4: Other Applications for Pavement Management Data and Analysis



Practice gaps identified by stakeholders related to other desired uses of pavement management data and analysis results are summarized below.

- Tracking and analyzing maintenance in a PMS.
- Using PMS data to support maintenance decision making.
- Perceiving pavement management solely as a condition reporting function rather than realizing the myriad potential uses of the data.
- Excluding the use of pavement management data to calibrate or validate pavement design models.
- Adapting the pavement management system to easily respond to changes in agency analysis demands.
- Understanding the systems well enough to be able to identify other opportunities to use PMS data.
- Failing to have adequate time to involve data scientists and other specialists in the analysis of how to optimize the use of available funding.
- Understanding the value and benefit of pavement management within an agency.



THEME 3: WORKFORCE AND ORGANIZATIONAL ISSUES

According to the baseline survey and stakeholder outreach activities, issues related to workforce development and organizational practices continue to hinder the full implementation of pavement management. Stakeholders indicated that external factors continue to influence funding levels and project selection, and the Coronavirus pandemic that started in 2020 emphasized the importance of considering uncertainty in a pavement management analysis. Transportation agencies report using more data than ever to support decisions and the data is coming from new public and private data sources, which are introducing challenges associated with data ownership, transparency, and reliability.

The increased reliance on data to support decisions is reported to have broadened the skills necessary to

analyze pavement management information and blurred the lines between engineering, economics, and risk during decision processes.

According to the participants in the stakeholder outreach sessions, workforce development is hindered by the limited availability of college-level and post-graduate training in pavement management. Pavement management practitioners benefit from a broad range of skills to be successful, such as having the technical skills to understand and model pavement performance as well as the communication skills to present results and successfully convey impacts. As the data used by pavement managers has changed with time, stakeholders report that skills in data analytics and data quality management have become increasingly important. Pavement management programs also continue to benefit from the availability of a strong champion who understands the way the agency operates, works well across functional areas, and has access to and support from upper management.

Data collection is often the most resource-intensive aspect of pavement management, so organizational priorities that impact the availability of funding to conduct periodic condition surveys can impact system reliability. Building an understanding of the importance of this data within the agency, while also considering strategies that could streamline the agency's data collection processes, could be important to the long-term viability of the data necessary to support data-driven decisions.

Pavement management practitioners are also indicating increasing responsibilities related to project selection to help ensure that the 10-year investments outlined in the TAMP are reflected in the construction program. Stakeholders report that establishing asset investment levels increasingly involves trade-off decisions that depend on the ability to forecast future conditions quickly and reliably under a variety of funding scenarios.

Further complicating these issues is the speed with which technology changes. For small agencies, especially those doing most of the work inhouse, changes in technology can happen at speeds that are much faster than can be reasonably implemented. Stakeholder outreach activities noted the importance of agency agility to effectively manage data quality and use the increasing volume, velocity, and variety of data collected with rapidly changing technologies. The ability to critically assess the capabilities of new and existing technology, and use the technology effectively, were important capabilities identified by the pavement management community.

Topic Area 3-1: People

Practice gaps identified by stakeholders related to personnel aspects of pavement management are summarized below.

- Planning for and implementing staff transitions due to promotions, retirements, or other forms of personnel changes.
- Availability of training for pavement management practitioners on an on-call basis to enhance skills in data quality management, performance modeling, and other technical areas.



- Perceiving technical career tracks as less desirable in terms of moving up in an organization so pavement management becomes a steppingstone rather than a long-term career choice.
- Lacking redundancy in staffing because resources are stretched too thinly.
- Accessibility to resources that provide the type of comprehensive technical assistance for pavement management practitioners to perform their duties with confidence.
- Documenting pavement management practices to support staff transitions is hindered by the lack of references, templates, and time availability.

Topic Area 3-2: Pavement Management Funding Risks

Practice gaps identified by stakeholders related to the funding availability to support the data collection and software for pavement management are summarized below.



- Effectively describing funding impacts to influence investment decisions and project selection decisions so they better align with pavement management project suggestions.
- Quantifying the benefits associated with good data to offset pressure to decrease funding for data collection activities.
- Dealing with unreliable funding sources to support pavement management activities, which could lead to future credibility issues.
- Lacking secure resources for on-going data collection efforts.
- Correlating pavement management project suggestions with economic vitality impacts to demonstrate the benefits to preservation investment.
- Fluctuating funding for preservation that impacts the ability to apply treatments at the optimal time.
- Dealing with many different and unpredictable funding sources that complicate the budgeting process.

Topic Area 3-3: Integration into Existing Systems and Processes

Practice gaps identified by stakeholders related to the integration of pavement management with other systems and processes are summarized below.



- Overcoming resistance to the use of pavement management information to support a broader range of analysis demands within an agency.
- Relying on traditional, lagging performance measures that track impacts after decisions are made rather than leading measures that have the potential to influence decisions before they are made.
- Missing data on factors that influence project selection decisions such as environmental sustainability and resilience, equitable access to transportation, and economic vitality.
- Having assistance available to support efforts to streamline agency data collection efforts across the organization.

- Dealing with organizational structure impediments to integration.
- Relying on what is known or comfortable with respect to pavement management rather than reaching out to others in the organization.
- Building agency confidence in the value provided in using pavement management project suggestions to support investment decisions.

Topic Area 3-4: Data and Technology

Practice gaps identified by stakeholders related to the use of data and technology are summarized below.



- Efficiently integrating various data sources (e.g., maintenance, pavement design, construction) to support the comprehensive analysis of pavement life cycle strategies.
- Designing and managing data quality management programs related to equipment calibration, rater certification, quality acceptance testing, and resolution strategies.
- Adopting innovation in government agencies in a timely manner without fear of repercussions for failure.
- Converting data into meaningful information on a consistent basis.
- Establishing comprehensive data sets on which to base project suggestions.
- Overcoming reluctance to change so that innovations and institutional changes can be adopted.
- Lacking data analysts and analytical tools to get the most out of available data.

Topic Area 3-5: Communication and Outreach

Practice gaps identified by stakeholders related to the ability to convey pavement management information effectively are summarized below.



- Presenting pavement management information in a way that resonates with a variety of stakeholders.
- Transitioning roles and responsibilities when pavement management champions retire, are promoted, or leave the agency.
- Building an understanding of pavement management strategies among the public.
- Communicating across silos.
- Dealing with conflicting data sources.
- Accessing practices in other agencies that could be adopted.



THEME 4: TECHNOLOGICAL ADVANCEMENTS – NEW TOOLS, METHODOLOGIES, AND TECHNOLOGY

Technological advancements identified during the gap assessment cover the gamut of pavement management from data collection, analysis, application, and so on. This theme includes changes in equipment (such as increased computing power, higher definition cameras, and more accurate and precise sensors) as well as enhancements to analysis tools (such as artificial intelligence). Technologies such as smartphones and UAS are also influencing research and practice. All of these areas have progressed over the last decade, but the demand for improvement and adoption in these areas continues.

Automated data collection and data interpretation technologies are an area of high interest among pavement management stakeholders who participated in this project. These technologies have become more affordable, and the baseline survey indicates their adoption over manual methodologies for network-level pavement management has increased over the last decade. The focus over the last few years has been on enhancing the resolution of 3D pavement surface imagery data to improve the consistency and accuracy of pavement condition data used for pavement management. In 2018, AASHTO published a voluntary industry specification (AASHTO R85) that outlines protocols for quantifying cracking distresses on asphalt pavements at the network level. According to the gap assessment, a fully automated methodology for interpreting pavement surface distresses by automated data collection devices is not readily available. Existing automated interpretation methods primarily focus on asphalt-surfaced pavements and can help automate the identification of some distress (such as longitudinal cracking, transverse cracking, and generic pattern cracking), but more nuanced assessments (for detection of distress such as weathering, raveling, and slippage cracking) are not possible with existing techniques. Moreover, many of the distresses on concrete-surface pavements are not identified accurately using automated interpretation methods.

With the advent of new technologies, backward compatibility with historical data continues to be an issue for pavement management stakeholders. Agencies facing these types of challenges may find it useful to determine which historical data can and cannot be used moving forward.

Changes in the types of information that can be collected using new technology is also impacting pavement management. For instance, the baseline survey indicated there was strong interest in assessing pavement structural conditions at the network level, using technologies such as TSDD to inform treatment and funding decisions. GPR use was also noted for establishing layer thickness profiles, detecting subsurface voids, and other purposes. Information on the appropriate use of GPR data for making network-level decisions and practices for incorporating TSDD data into a PMS are still lacking. The lack of available information could be a reason these technologies are not used widely for pavement management.

Changes in technology are also influencing the way data is collected, as noted by stakeholder interest in UAS, light detection and ranging (LiDAR), smartphones and other crowd-sourced pavement ride quality and condition assessments, and CAVs. While these technologies are reportedly being deployed by a few agencies in small-scale efforts, there is little information available on the suitable use of these technologies for pavement management purposes. Emerging technology has the potential to bridge some existing gaps by helping reduce the time lag between data collection and the availability of results in pavement management. This time lag, which was reported to be 3 to 6 months, can impact the usefulness of pavement management data to support planning and programming activities.

Changes in technology are also improving the analysis tools available to support pavement management, such as the use of the cloud for accessing PMS tools. However, demands on staffing reportedly limit practitioners' ability to build pavement management skills, which may lead to hesitation to upgrade software if it would demand more training to learn how to use it.

From a systems perspective, additional changes in pavement management software may be beneficial to consider the environmental, financial, and social aspects that influence project selection decisions. As these factors gain prominence in pavement management, new performance measures that support these initiatives will likely be developed. Together with the increased desire to use leading measures that improve pavement life cycle management, these changes in pavement performance models have the potential to pave the way for the next generation of pavement managers and pavement management systems.

Topic Area 4-1: Advancements in Automated Pavement Data Collection Technologies

Practice gaps identified by stakeholders related to advancements in automated pavement data collection technologies are summarized below.

- Identifying distresses beyond simple longitudinal, transverse, and pattern cracking from automated pavement data interpretation technologies.
- Characterizing pavement surface type (beyond just asphalt and concrete) and other surface characteristics (such as oxidation and weathering).
- Consolidating pavement data collection efforts.



- Improving consistency in the data collected and reported.
- Assessing the compatibility of data obtained using new technology with historical data.
- Using new technology, such as UAVs and CAVs, to support pavement management.

Topic Area 4-2: Technologies to Assess Pavement Subsurface Characteristics and Structural Properties

Practice gaps identified by stakeholders related to the use of technology to assess pavement subsurface characteristics and structural properties are summarized below.



- Using network-level GPR data for pavement management analysis.
- Addressing variability in the measurements from the TSDD.
- Understanding how to incorporate TSDD data into pavement management decision making.
- Clarifying how GPR and TSDD data can be used to support pavement management.

Topic Area 4-3: Emerging Data Collection Technologies and Methodologies for Assessing Pavement Distresses and Other Surface Characteristics

Practice gaps identified by stakeholders related to the use of emerging data collection technologies and methodologies for assessing pavement distresses and other surface characteristics are summarized below.



- Evaluating the emerging data collection technologies and methodologies (e.g., UAS, LiDAR, smartphone-based ride data, CAVs) for use in pavement management.
- Quantifying costs and benefits associated with the use of emerging data collection approaches to support pavement management decision-making.
- Assessing drainage conditions and pavement oxidation.

Topic Area 4-4: Improving Pavement Management Data and Analysis Tools

Practice gaps identified by stakeholders related to improving pavement management data and analysis tools are summarized below.

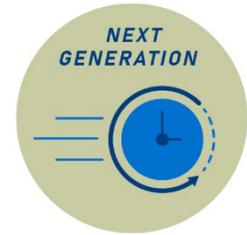


- Processing data in real-time using emerging tools and technologies.
- Identifying the appropriate tools and techniques for analyzing pavement management data.

- Integrating risk assessment into pavement management systems.
- Assessing and addressing missing data in the PMS decision-making process.
- Considering how pavement management project suggestions improve resiliency.
- Explaining pavement performance and justifying planned investments to decision makers in a meaningful way.

Topic Area 4-5: Next Generation Performance Measures

Practice gaps identified by stakeholders related to the use of the next generation of pavement performance measures are summarized below.



- Integrating financial sustainability aspects within pavement management.
- Considering environmental factors within pavement management.
- Considering social justice factors within pavement management.
- Harmonizing State and Federal performance measures.
- Communicating the return on investment associated with pavement management project suggestions.

ESTABLISHING PRIORITIES

The final stakeholder outreach session provided an opportunity for participants to establish priorities for addressing gaps using an online ranking tool. For most action categories, participants were asked to rank the importance of an item using a 0 to 5 scale, with a 5 representing the highest priority. Since the final list of action items was not available at the time the ranking was conducted, not all action items were ranked. However, the rankings provide insight into the urgency with which some topics should be addressed and influenced the suggestions in the later sections of this *Roadmap*. A summary of the top stakeholder rankings in each action category is provided in Appendix B.

3.0 10-YEAR PAVEMENT MANAGEMENT ROADMAP

LONG-TERM VISION FOR PAVEMENT MANAGEMENT

The 2010 Pavement Management *Roadmap* established a vision for pavement management in 2020 that stated:

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 demands at the project, network, and strategic levels.

To better support the implementation of this updated *Pavement Management Roadmap*, the previous vision has been updated to extend its applicability well beyond the 10-year period outlined in this document. Supporting principles are also provided to establish the framework for implementing the suggestions outlined in the *Roadmap*.

Pavement Management Vision

The updated vision for pavement management is presented in the following graphic. It emphasizes the importance of efficiency and effectiveness in all aspects of pavement management from data collection and analysis to the presentation and use of the data.

PAVEMENT MANAGEMENT VISION

Pavement management supports agency investment decisions using quality data and analysis tools that encourage the consideration of long-term consequences on pavement and system performance in alignment with building safe, sustainable, and equitable transportation systems.

This vision is achievable with the following:

- Efficient and effective data collection and analysis procedures that take advantage of promising new technologies to produce the most reliable and valid data possible within resource constraints.
- Access to data and analytical tools that are robust, comprehensive, and credible.
- The ability to communicate effectively with stakeholders using performance data that consider strategic objectives (such as economic and financial sustainability, risk and resilience, and social equity) in addition to pavement condition.
- Deployment of a well-trained and effective work force with access to resources that build and enrich the skills needed to effectively manage a pavement network.
- Internal and external support for pavement management that recognizes the benefits and value provided through its use in supporting planning, programming, design, construction, and maintenance activities.

IMPROVEMENT AREAS

To address the gaps identified during the *Roadmap's* development and achieve the long-term vision, a series of activities are suggested in the tables included in the remainder of this section. These activities are organized into the 15 different Improvement Areas (IAs) listed below and summarized in the graphic.



DATA

- Data Collection** — Improve the efficiency and reliability of existing data collection,
- Data Quality** — Improve the quality of data collection using traditional processes.
- Data Management** — Support efforts to improve data processes and management.



ANALYSIS

- Performance Modeling** — Enhance the reliability and level of confidence in pavement performance models.
- Treatment Rules and Impacts** — Refine treatment rules and impacts to improve project and treatment suggestions.
- PMS Analysis** — Strengthen the use of pavement management software to support agency investment- and project-planning decisions.
- Performance Measures** — Support the expanded use of existing performance measures at the Federal, State, and local levels.



WORKFORCE

- Training** — Develop and deploy content to support workforce development.
- Workforce Development** — Reduce barriers to ready access to training and information needed to support workforce transitions.
- Technical Assistance** — Provide support to promote the use of pavement management concepts.
- Tools** — Support the development of software tools to supplement existing capabilities.
- Communication** — Develop effective tools for strategies for communicating pavement management results to different stakeholders.
- Organizational Challenges** — Address organizational challenges that hinder the use of pavement management



NEW TECHNOLOGY

- New Technology** — Promote strategies for using new technology to support pavement management data collection and analysis.
- Next Generation Performance Measures** — Implement next generation performance measures into pavement management programs.

Theme 1: Data

1. Data Collection - Improve the efficiency and reliability of existing data collection.
2. Data Quality – Improve the quality of data collection using traditional processes.
3. Data Management – Support efforts to improve data processes and management.

Theme 2: Pavement Management Analysis Tools and Other Applications

1. Performance Modeling - Enhance the reliability and level of confidence in pavement performance models.
2. Treatment Rules and Impacts – Refine treatment rules and impacts to improve project and treatment suggestions.
3. PMS Analysis – Strengthen the use of pavement management software to support long-term agency investment- and project-planning decisions through LCP.
4. Performance Measures – Support the expanded use of existing performance measures at the Federal, State, and local levels.

Theme 3: Workforce and Organizational Issues

1. Training – Develop and deploy content to support workforce development.
2. Workforce Development - Reduce barriers to ready access to training and information to support workforce transitions. This could be done through training programs, peer exchanges, and other methods of deployment.
3. Technical Assistance – Provide support to promote the use of pavement management concepts.
4. Tools – Support the development of software tools to supplement existing capabilities.
5. Communication – Develop effective tools for strategies for communicating pavement management results to different stakeholders.
6. Organizational Challenges – Address organizational challenges that hinder the use of pavement management

Theme 4: Technological Advancements – New Tools, Methodologies, and Technology

1. New Technology – Promote strategies for using new technology to support pavement management data collection and analysis.
2. Next Generation Performance Measures – Implement next generation performance measures into pavement management programs.

Within each Improvement Area, specific suggested action items are identified. These action items describe activities that are desired within the following areas.



■ **Research** – Action items in this area involve some research and development to put the concepts into practice. Typical funding sources for these types of actions include the FHWA Office of Infrastructure, the FHWA Office of Infrastructure Research and Development, including work conducted by the FHWA Long-Term Pavement Performance (LTPP) Program or the Turner-Fairbank Research Center, and the NCHRP. Transportation Pooled Fund (TPF) Program studies are another method of conducting research.



■ **Deployment** – This category includes actions that help agencies use pavement management concepts or technology. Action items in this category do not necessarily involve research to put the concepts into practice, but agencies would benefit from information on how to apply the concepts effectively. The FHWA’s Infrastructure Research and Technology Deployment Program within the Office of Infrastructure, the Tribal Technical Assistance Program (TTAP), NCHRP, and TPF are likely sources of funding.



■ **Technical Assistance** – Action items in this category would benefit from direct technical support to a particular agency that is adopting new concepts or transitioning to new pavement management innovations. The FHWA, NCHRP, and AASHTO may be funding sources.



■ **Syntheses** – A synthesis is a summary of current practice that may be funded by NCHRP or another source.



■ **Peer Exchanges** – Identified by stakeholders as the most effective method of implementation support, peer exchanges provide an opportunity for peer agencies to come together to share practices and ideas. In the past, the FHWA has conducted pavement management peer exchanges regularly.



■ **Training** – Action items in this category include the development of training materials that can be provided through online courses, instructor-led courses, or hybrid courses that combine online and in-person training. The FHWA’s National Highway Institute (NHI), Local Technical Assistance Programs (LTAPs), and Tribal Technical Assistance Program (TTAP) are examples of technical services that might support training development.



■ **Case Studies** – Case studies illustrate the application of a concept or methodology in one or more agencies through published material. The FHWA commonly uses case studies to describe well-established practices that might benefit other agencies.



■ **Tool Development** – Action items in this area involve the development of public-domain software tools that enhance existing analysis capabilities. These tools may be developed by private industry or may be supported by Federal agencies, such as the FHWA’s LTPP Program.

In total, the 15 IAs include 72 action items, representing a total of approximately \$30.225 million in needed funding. Of the 72 action items, 46 represent short-term activities that can be completed within the next 5 years and the remaining 26 are identified as long-term activities that can be accomplished in the next 6 to 10 years. More comprehensive descriptions and estimated costs for each action item in are provided in Appendix C. Suggestions for implementing the *Roadmap* can be found in the next section.

Theme	Number of Improvement Areas	Number of Action Items	Number of Short-Term Action Items	Number of Long-Term Action Items
1: Data	3	20	14	6
2: Pavement Management Analysis Tools and Other Applications	4	20	16	4
3: Workforce and Organizational Issues	6	24	14	10
4: Technological Advancements: New Tools, Methodology, and Technology	2	8	2	6
Totals	15	72	46	26

SUGGESTED ACTION ITEMS BY THEME

This section presents each action item by theme. These suggested action items are presented as actions, that, if completed, would advance the state of the practice of pavement management. No commitments to funding the suggestions contained in the *Roadmap* are implied by the FHWA or any other agency.

Theme 1: Data

Theme 1 had a total of \$6.375 million in suggested action items, as presented in the following table.

Number	Suggested Action Item	Category of Work	Short- or Long-Term	Estimated Cost
1. Improve the efficiency and reliability of existing data collection efforts (Data Collection)				
1A	Conduct research to determine the impact of survey extent, frequency, precision, and other data quality issues on predicted conditions and project suggestions, including the cost-benefit of data quality efforts and the consequences of poor data. Develop a Data Collection Playbook on how to apply the findings at the Federal, state, and local levels	Research	Long	\$500,000
1B	Evaluate the feasibility and cost-effectiveness of incorporating friction testing, structural deflection, ROW imaging, and asset takeoff into existing network-level survey processes	Research	Long	\$150,000
1C	Improve 3D data collection and interpretation technologies to enable automated identification of a broader range of pavement distress with improved consistency on both asphalt and concrete pavement	Research	Short	\$750,000
1D	Synthesize practices regarding the collection of inventory and condition data on lower-level roadways, shoulders, and ramps, and the benefits associated with collecting this information	Synthesis	Short	\$50,000
1E	Synthesize successful practices on contracting for pavement management data collection	Synthesis	Short	\$50,000
1F	Conduct a peer exchange to discuss strategies for addressing contracting issues associated with data collection activities and improving the timeliness of survey data	Peer Exchange	Short	\$75,000
1G	Develop deployment materials on strategies for: <ul style="list-style-type: none"> • Contracting data collection activities • Use of TSDD data to define network structural condition • Quantifying the value of using network-level structural data in a PMS • Using GPR • Using macrotexture • Using existing equipment to collect asset inventory and condition information for curb ramps, signage, sidewalks, curb and gutter, and other information • Integrating utility information into a PMS • Streamlining data collection activities 	Deployment	Short	\$600,000

Number	Suggested Action Item	Category of Work	Short- or Long-Term	Estimated Cost
2. Improve the quality of data collected using traditional procedures (Data Quality)				
2A	Develop methods for characterizing pavement surface characteristics that use a combination of existing and new techniques	Research	Long	\$350,000
2B	Develop consistent nonregulatory distress definitions and criteria using automated data collection procedures	Research	Short	\$400,000
2C	Develop consistent nonregulatory criteria for rutting certification and verification	Research	Short	\$150,000
2D	Develop consistent nonregulatory criteria for network-level pavement structural health assessments	Research	Long	\$250,000
2E	Establish a framework for documenting the benefits of good data, pilot the framework, and promote the findings	Research	Long	\$250,000
2F	Conduct a peer exchange to discuss how agencies are a) addressing challenges in data collection equipment transitions, b) reconciling differences temporally and spatially, c) verifying cracking, transverse profile, and faulting values, d) developing stability in ratings when protocols/practices change, e) preparing and following an effective DQMP, establishing data acceptance criteria	Peer Exchange	Short	\$75,000
2G	Develop deployment strategies for: <ul style="list-style-type: none"> Addressing challenges with transitions in procedures and addressing differences temporally and spatially Improving consistency between raters and/or years Implementing automated data quality checks and processes for interim data acceptance Using the acceptance criteria established through the FHWA Pooled Fund TPF-5(299) and (399) Using data sampling Certifying equipment and operators 	Deployment	Short	\$175,000
2H	Develop and pilot a framework for addressing the road data deficiencies on Tribal lands	Deployment	Short	\$750,000
3. Support efforts to improve data processing and management (Data Management)				
3A	Conduct a study on cost-effective methods of storing large amounts of data over time, including suggestions for archiving and retrieving data	Research	Short	\$750,000
3B	Develop and pilot a methodology for using artificial intelligence, machine learning, citizen and data science applications to improve the reliability and timeliness of pavement management data	Research	Long	\$750,000
3C	Synthesize agency policies on data storage, including any limitations imposed by oversight agencies	Synthesis	Short	\$50,000
3D	Conduct a peer exchange to address the use of BIM/CIM and e-construction data to populate pavement histories	Peer Exchange	Short	\$75,000
3E	Develop deployment strategies for: <ul style="list-style-type: none"> Integrating various data sources, including LRS issues Storing large amounts of data Documenting data with proper metadata 	Deployment	Short	\$175,000

Theme 2: Pavement Management Analysis Tools and Other Applications

Theme 2 had a total of \$4.825 million in suggested action items.

Number	Suggested Action Item	Category of Work	Short- or Long-Term	Estimated Cost
4. Enhance the reliability and level of confidence in pavement performance models (Performance Modeling)				
4A	Investigate and summarize the impact of using pre-treatment and material properties in pavement performance models	Research	Short	\$250,000
4B	Develop and pilot a framework for the consideration of extreme weather changes, traffic variability, environmental sustainability, and other risk factors in pavement performance modeling	Research	Short	\$250,000
4C	Develop and pilot pavement performance modeling techniques that a) account for “noisy data” and changes in design, traffic, and other variables and b) explain how to deal with outliers and missing data	Research	Long	\$200,000
4D	Conduct a peer exchange to discuss techniques and practices associated with pavement performance modeling	Peer Exchange	Short	\$75,000
4E	Develop deployment strategies for: <ul style="list-style-type: none"> • Developing performance models, including techniques for modeling with no historic data • Evaluating model reasonableness and reliability • Determining when models should be updated • Developing performance models using TSDD data • Incorporating risk into models, including future environmental risks • Evaluating the impact of risk on project conditions • Using models to calibrate pavement design procedures • Using data science to evaluate trends and treatment effectiveness • Documenting models 	Deployment	Short	\$350,000
4F	Develop a tool to predict pavement performance based on LTPP data (default) or using a State’s pavement management data	Tool Development	Short	\$750,000
5. Refine treatment rules and impacts to improve project and treatment suggestions (Treatment Rules and Impacts)				
5A	Develop and pilot a methodology to quantify the impact and performance of preventive maintenance activities using readily available pavement management data	Research	Short	\$300,000
5B	Develop deployment strategies for: <ul style="list-style-type: none"> • Incorporating maintenance and preventive maintenance treatments into a PMS • Incorporating TSDD results into decision trees • Determining conditions under which treatments are viable (e.g., proactive maintenance, low or high preservation, minor or major rehabilitation) • Considering variations in existing conditions when defining the impact of preventive maintenance treatments • Documenting treatment rules 	Deployment	Short	\$175,000

Number	Suggested Action Item	Category of Work	Short- or Long-Term	Estimated Cost
6. Strengthen the use of pavement management software to support agency investment and project-planning demands (PMS Analysis)				
6A	Develop and pilot a framework for the consideration of factors such as social equity, sustainability, and resilience in a pavement management analysis	Research	Short	\$350,000
6B	Develop deployment materials on aligning pavement management suggestions with programmed projects and instituting a feedback loop to account for reasonable exceptions.	Deployment	Short	\$175,000
6C	Develop and pilot a framework for integrating maintenance data into pavement management and promoting the use of pavement management data for maintenance planning	Research	Long	\$250,000
6D	Develop guidelines for accounting for other models of travel (e.g., pedestrians, bikes, and scooters) in developing pavement management project suggestions	Research	Short	\$350,000
6E	Develop and pilot a framework for integrating construction costs and life cycle assessments (LCAs) into pavement management	Research	Long	\$400,000
6F	Conduct a peer exchange to discuss a) how a PMS is used to support life cycle planning, b) typical matches between analysis results and projects, and c) use of PMS data to support other departments	Peer Exchange	Short	\$75,000
6G	Develop deployment strategies for: <ul style="list-style-type: none"> Establishing an effective feedback loop Determining whether new software tools are necessary Using PMS results in a multi-objective project selection process Incorporating risk and resilience into an analysis Selecting projects that improve agency resilience Evaluating the impact that new developments have on conditions when assessing future funding demands Defining “backlog” 	Deployment	Short	\$175,000
6H	Summarize effective data visualization and communication efforts to support project selection and scoping	Synthesis	Short	\$50,000
7. Support the expanded use of existing performance measures at the Federal, State, and local levels (Performance Measures)				
7A	Identify strategies for addressing the reporting, target setting, and analysis implications of the 0.1-mile Federal requirements (23 CFR 490.309)	Research	Short	\$150,000
7B	Summarize the use of performance measures to support pavement management in urban areas and develop strategies on using pavement performance measures effectively in an urban environment	Research	Long	\$250,000
7C	Conduct a peer exchange to discuss a) how agencies are explaining and analyzing differences in State and Federal measures, b) strategies to improve Federal measures, and c) how to use pavement management data to set performance targets	Peer Exchange	Short	\$75,000
7D	Develop deployment strategies for data-driven target setting	Deployment	Short	\$175,000

Theme 3: Workforce and Organizational Issues

Theme 3 had a total of \$15.5 million in suggested action items.

Number	Suggested Action Item	Category of Work	Short- or Long-Term	Estimated Cost
8. Develop and deploy content to support workforce development (Training)				
8A	Develop training on: <ul style="list-style-type: none"> • Pavement data collection strategies • Basic statistics • Data quality management plans and how to use them • Equipment calibration and certification practices • Other data quality topics, including data sampling and reviewing processes, error resolution, pre-processing techniques to address data issues, rater certification • Data science applications for pavement management • Structured Query Language (SQL) programming skills • Pavement performance modeling, including data elements, model types, and statistical acceptance • Using structure data and other information to support project and treatment selection • Building pavement management champions • Data integration 	Training	Short	\$750,000
8B	Conduct workshops to share deployment materials on: <ul style="list-style-type: none"> • How to use GPR data for project selection • Use of TSDD data in decision trees and performance models • Data integration • Using pavement management for life cycle planning • The development and use of leading performance measures 	Training	Short	\$1,000,000
8C	Develop and implement a Peer-to-Peer training program	Training	Long	\$250,000
8D	Redesign the FHWA's PMS User's Group to focus more on training	Training	Short	\$500,000
8E	Conduct book club sessions on the updated Pavement Management Guide when finished	Training	Long	\$150,000
8F	Conduct workshops on the updated Pavement Management Guide at conferences	Training	Long	\$0
8G	Incorporate updated training materials into a Pavement Management Leadership Academy to build skills and raise pavement management's profile	Training	Long	\$500,000
9. Reduce barriers to ready access to training and deployment strategies to support workforce transitions (Workforce Development)				
9A	Identify feasible strategies to enhance local access to pavement management training materials	Research	Short	\$125,000
9B	Develop an updated, online, searchable, Pavement Management Guide to address current topics	Research	Short	\$500,000
9C	Develop and make available templates for documenting pavement management models, treatment rules, processes, and procedures	Research	Short	\$400,000
9D	Create on-the-job and just-in-time training materials	Training	Short	\$600,000

Number	Suggested Action Item	Category of Work	Short- or Long-Term	Estimated Cost
10. Provide support to promote the use of pavement management concepts (Technical Assistance)				
10A	Pilot and implement a technical assistance program on: <ul style="list-style-type: none"> Data management, data quality, the use of untapped data, and other data-related issues Pavement performance modeling and use of a feedback loop Documenting pavement management practices 	Technical Assistance	Short	\$400,000
10B	Develop a National Equipment Certification Center	Technical Assistance	Long	\$1,500,000
10C	Conduct pilot programs to demonstrate: <ul style="list-style-type: none"> The use of new technology Benefits to using the next generation performance measures Return on investment from using GPR and TSDD data Strategies for using PMS data to support multi-objective decision analysis and cross-asset tradeoff analysis The conversion of research results into practice Use of PMS data to support maintenance scheduling and planning Successful transition strategies (such as recruiting, retention, training, and promotion) 	Technical Assistance	Long	\$1,400,000
10D	Develop an equipment loan program to provide agencies an opportunity to test new technology	Technical Assistance	Short	\$600,000
10E	Develop a program to support new technology trials	Technical Assistance	Long	\$5,000,000
10F	Develop and support an equipment and new technology demonstration program at the university level to train students	Training	Long	\$300,000
11. Support the Development of Software Tools to Supplement Existing Capabilities (Tools)				
11A	Develop a consistent, automated data checking tool to evaluate submittals by data vendors in accordance with the DQMP	Tool Development	Short	\$300,000
11B	Create software for accessing images from data collection efforts beyond the 5 years available from vendors	Tool Development	Long	\$500,000
11C	Support vendor software modifications to better enable an LCP analysis and the use of next -generation pavement performance measures	Tool Development	Long	\$0
12. Develop effective tools and strategies for communicating pavement management results to different types of stakeholders (Communication)				
12A	Develop deployment strategies on presenting pavement management outputs and communicating the long-term impact of deferred investment	Deployment	Short	\$175,000
12B	Create sharable materials that convey pavement management messaging for the public that can be placed on an agency's website	Training	Short	\$150,000

Number	Suggested Action Item	Category of Work	Short- or Long-Term	Estimated Cost
13. Address organizational challenges that hinder the successful use of pavement management (Organizational Challenges)				
13A	Document success stories where consistent funding for pavement management updates has led to improvements in network conditions and contrast this with agencies where funding has not been consistent	Case Studies	Short	\$150,000
13B	Develop deployment strategies for overcoming organizational silos that impact pavement management, recognizing the benefits to cross training, multi-discipline collaboration, and succession planning.	Deployment	Short	\$250,000

Theme 4: Technological Advancements – New Tools, Methodologies, and Technology

Theme 4 had a total of \$3.525 million in suggested action items.

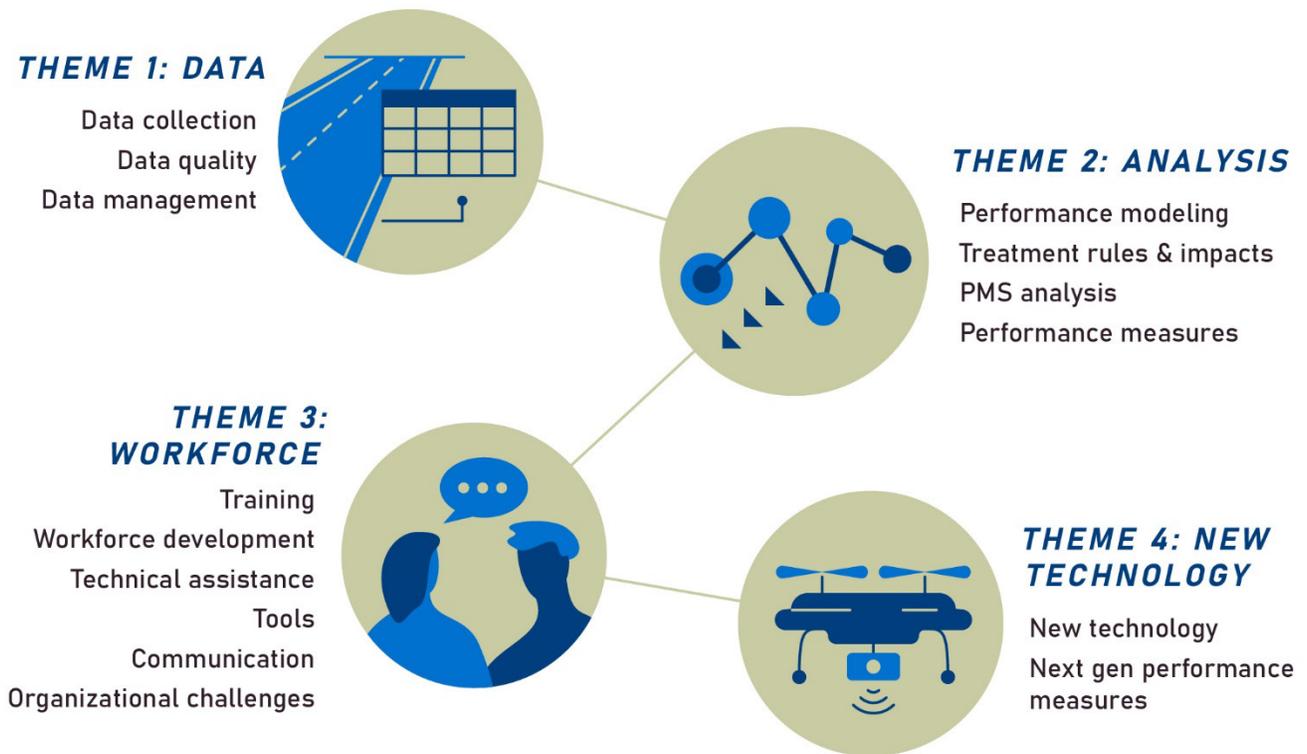
Number	Suggested Action Item	Category of Work	Short- or Long-Term	Estimated Cost
14. Promote strategies for using new technology to support pavement management data collection and analysis (New Technology)				
14A	Develop automated approaches for processing and analyzing pavement management data	Research	Long	\$350,000
14B	Develop technology to assess drainage conditions with minimal manual involvement	Research	Long	\$600,000
14C	Establish deployment strategies for: Using data from crowdsourced data, CAVs, UAS, and other automated technology to support pavement management analysis Documenting precision/bias statements that can be put into practice Using new technology in concert with traditional data collection practices Replacing outdated technology with proven new technology Applying the Technology Readiness Level Guidebook published by NASA to evaluate whether new technology is ready to be implemented	Deployment	Short	\$150,000
14D	Develop equipment to assess pavement structural condition on rigid pavements and on low-level roads where semis are not a viable option	Research	Long	\$1,000,000
14E	Develop equipment for continuous friction measurements	Research	Long	\$800,000
14F	Develop strategies to facilitate the implementation of university research to advance pavement management	Research	Long	\$175,000

Number	Suggested Action Item	Category of Work	Short- or Long-Term	Estimated Cost
15. Implement next generation performance measures into pavement management programs				
15A	Develop and pilot deployment materials on using leading measures, such as structural data, to influence pavement management decisions	Deployment	Short	\$200,000
15B	Develop and pilot deployment materials on the use of non-traditional performance measures (e.g., crash reduction, complete streets components, Americans with Disabilities Act (ADA)-compliant facilities, other travel modes, and social equity) to support project and treatment selection processes	Deployment	Long	\$250,000

4.0 PAVEMENT MANAGEMENT ROADMAP IMPLEMENTATION

ROADMAP HIGHLIGHTS

The implementation of the updated *Pavement Management Roadmap* involves the successful completion of the suggested action items identified within the 15 Improvement Areas shown below.



In total, the *Pavement Management Roadmap* presents 72 suggested action items that are estimated to cost \$30.225 million to complete. Of the 72 suggested action items, 46 are short-term activities to be completed in the next 5 years and the remaining 26 are long-term activities to be completed in years 6 to 10. These suggested action items are presented as actions, that, if completed, would advance the state of the practice in pavement management. No commitments to funding the suggestions contained in the *Roadmap* are implied by the FHWA or any other agency.



IMPLEMENTATION APPROACH

The implementation suggestions are expected to advance pavement management practices, provide workforce training, and align pavement management with agency needs. The implementation plan suggests possible project sponsors to support the development of solutions to common issues that will help advance innovative pavement management practices. No commitments to funding the suggestions contained in the *Roadmap* are implied by the FHWA or any other agency.

The implementation approach encourages collaborative efforts that leverage relationships with industry, academia, international entities, and transportation agencies at all levels to help reduce unnecessary duplication of effort.

The primary potential roles for the *Roadmap's* implementation are described here and summarized in a graphic at the end of this section.

Federal Highway Administration (FHWA)

The FHWA provides stewardship over the construction, maintenance, and preservation of the Nation's highways, bridges, and tunnels. In this capacity, the agency conducts research and provides technical assistance to State and local agencies to improve performance and encourage innovation. The short- and long-term action item identifiers presented below correspond to the action items presented in earlier tables.

- Research (primarily sponsored by the FHWA’s Office of Research, Development, and Technology or the Turner-Fairbank Highway Research Center)
 - Short-term: 4A, 4B, 7A
 - Long-term: 1A, 3B, 6C, 6E, 7B, 9C
- Development and deployment activities (primarily through technical program offices or the Tribal and Local Technical Assistance Programs)
 - Short-term: 1G, 2G, 2H, 3E, 4E, 5B, 6B, 6G, 7D, 12A, 13B, 14C, 15A, 15B
 - Long-term: None identified
- Training and workforce development (primarily through the National Highway Institute with support from Tribal and Local Technical Assistance Programs and program offices)
 - Short-term: 8A, 9A, 9D
 - Long-term: 8C, 8F, 8G
- Regional workshops (primarily through technical program offices)
 - Short-term: 8B
 - Long-term: None identified
- Case studies (primarily through technical program offices)
 - Short-term: 13A
 - Long-term: None identified
- Peer exchanges (suggested at least two annually through technical program offices)
 - Topic ideas: 1F, 2F, 3D, 4D, 6F, 7C
- Webinars (primarily through technical program offices)
 - Short-term: 8D
 - Long-term: 8E
- Tool development (primarily through the Long-Term Pavement Performance Program)
 - Short-term: 4F
- Technical assistance program (primarily through the Local and Tribal Technical Assistance Programs or the technical program offices).
 - Short-term: 10A, 10D
 - Long-term: 10B, 10C
- Other deployment activities (primarily through the technical program offices)
 - Short-term: 12B
 - Long-term: 10E

National Cooperative Highway Research Program (NCHRP)

The NCHRP is one of the primary funding sources for the development of research in areas impacting transportation agencies. Research studies are identified annually based on research topics identified by State transportation agencies, AASHTO committees, and the FHWA. The topics selected are submitted by the AASHTO Special Committee on Research to the AASHTO Board of Directors, the National Academies, and FHWA. NCHRP defines the scopes for the projects in collaboration with research panels established for each study.

The short- and long-term research suggestions listed below were identified through the *Roadmap* development process.

- Short-term research activities: 5A, 6A, 9B
- Long-term research activities: 1B, 2E, 4C, 6D, 14A, 14F

NCHRP also sponsors synthesis studies, which are summaries of current practice in a technical area. A synthesis is typically used to report on the state of the practice rather than advance the state of the practice. Anyone can submit a topic idea for a synthesis, but funding for synthesis topics is limited.

Several synthesis topic areas were identified, including 1D, 1E, 3C, and 6H.

American Association of State Highway Transportation Officials (AASHTO)

AASHTO is a nonprofit association representing the nation's State transportation departments. The agency works to educate the public and key decision makers about the importance of transportation and serves as a liaison between State DOTs and the Federal government. AASHTO leads the development of technical criteria used in many program areas and serves as a catalyst for agency improvement through training, direct technical assistance, and other practices.

Pooled Fund Studies

The Transportation Pooled Fund (TPF) Program was established to address problems, research activities, and technology transfer efforts with significant or widespread interest among State DOTs and FHWA. The Program allows Federal, State, regional, and local transportation agencies and other organizations to combine resources to support transportation research studies. The studies must be sponsored by either a State DOT or the FHWA. Work sponsored by the TPF can be conducted by transportation agencies, private companies, foundations, or colleges, and universities.

Several action items identified through the *Roadmap's* development could lend themselves well to short- or long-term TPF projects, as noted below.

- Short-term: 2B, 2C, 3A, 11A
- Long-term: 2A, 2D

Transportation Research Board (TRB)

TRB activities are served through the volunteer efforts of individuals serving on technical committees. Each committee proposes research ideas, shares research findings, sponsors special activities, and provides a forum to address current transportation issues. Most relevant to the *Pavement Management Roadmap* are the following Standing Committees:

- AKT10, Pavement Management Systems.
- AKP40, Pavement Structural Testing and Evaluation.
- AKP50, Pavement Surface Properties and Vehicle Interaction.
- AKP10, Pavement Condition Evaluation.

These committees' responsibilities related to the implementation of the *Roadmap* include activities listed below.

- Developing comprehensive Research Needs Statements (RNS) related to the action items outlined in the *Roadmap*.
- Working with AASHTO members and committees to promote the RNS for funding.
- Serving as members of the Technical Panels for projects related to pavement management.
- Hosting at least one webinar per year on a topic area rated as a high priority by stakeholders involved in the *Roadmap's* development.
- Suggesting and supporting workshops and technical sessions at Pavement Management Conferences to address high-interest areas identified in the *Roadmap*.

Private Industry

Private industry serves a role in developing and enhancing the equipment used for data collection and processing, the software used for analyzing data, and the methods used for managing pavements. During the development of the *Pavement Management Roadmap*, several short- and long-term development opportunities were identified that would benefit from private industry participation.

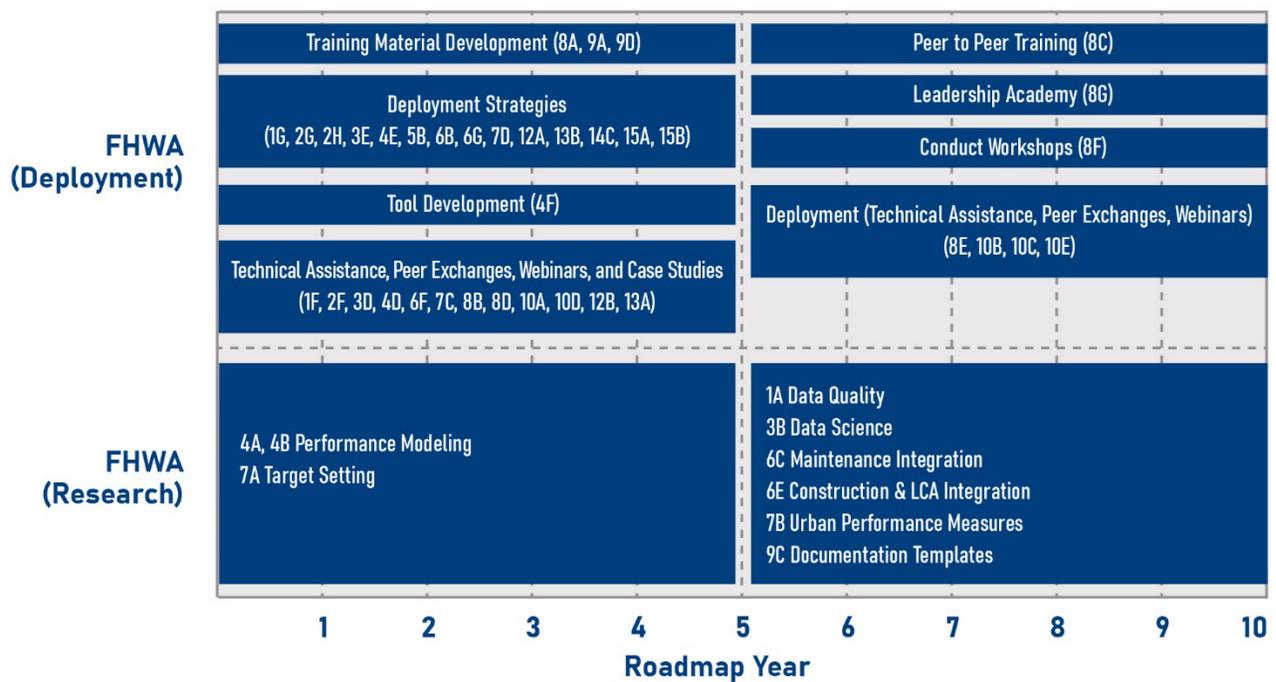
- Short-term: 1C
- Long-term: 11B, 11C, 14B, 14D, 14E

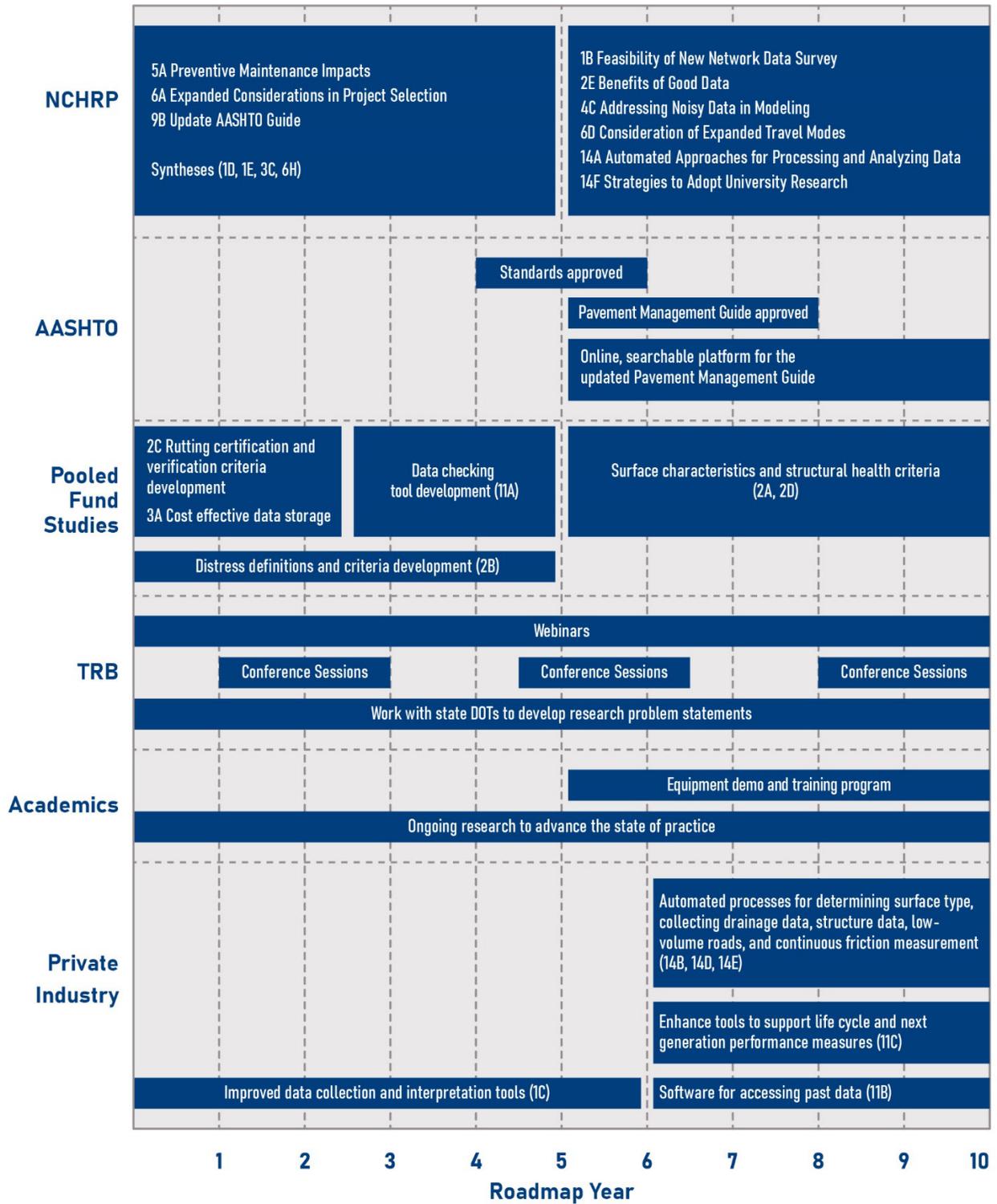
Academia

Colleges and universities play an important role in preparing graduates for careers in transportation. During the development of the *Roadmap*, several opportunities were identified for academics to support its implementation, as noted below.

- Conduct research in high-priority areas noted in the *Roadmap* that help to advance the state of practice.
- Work with State DOTs to establish an equipment demonstration and training program to support the education of college students in pavement management (10F).

Summary of Action Items By Organization





APPENDIX A – RELEVANT ACRONYMS & GLOSSARY

ACRONYMS

AASHTO	American Association of State Highway Transportation Officials
ADA	Americans with Disabilities Act
AI	Artificial Intelligence
BIA	Bureau of Indian Affairs
BIM	Building Information Modeling
CAV	Connected and Automated Vehicles
CFR	Code of Federal Regulations
CIM	Construction/Civil Information Modeling
DOT	Department of Transportation
DQMP	Data Quality Management Program
FAST	Fixing America’s Surface Transportation Act
FHWA	Federal Highway Administration
FWD	Falling Weight Deflectometer
GAO	Government Accountability Office
GIS	Geographic Information System
GPR	Ground Penetrating Radar
GPS	Global Positioning System
IAs	Improvement Areas
LCA	Life Cycle Assessment
LCP	Life Cycle Planning

LiDAR	Light Detection and Ranging
LRS	Linear Referencing System
LTAP	Local Technical Assistance Program
LTPP	Long-Term Pavement Performance
MAP-21	Moving Ahead for Progress in the 21 st Century Act
NASA	National Aeronautics and Space Administration
NCHRP	National Cooperative Highway Research Program
NHS	National Highway System
PMG	Pavement Management Guide
PMS	Pavement Management System
RNS	Research Needs Statement
ROW	Right of Way
SOGR	State of Good Repair
SQL	Structured Query Language
TAM	Transportation Asset Management
TAMP	Transportation Asset Management Plan
TPF	Transportation Pooled Fund
TPM	Transportation Performance Management
TRB	Transportation Research Board
TSDD	Traffic-Speed Deflection Device
TTAP	Tribal Technical Assistance Program
UAS	Unmanned Aircraft System
UAV	Unmanned Aerial Vehicle
USC	United States Code
USDOT	United State Department of Transportation

GLOSSARY⁶

Alternatives – Available choices or courses of action that can be considered at each stage of resource allocation or utilization.

Asset – The Pavement Management Guide defines assets as “physical infrastructure (e.g., pavements, structures, roadside features). Assets can also include other agency resources capable of providing added value (e.g., human resources, real estate, equipment, and materials).” FHWA asset management regulations at 23 CFR 515.5 define assets as “all physical highway infrastructure located within the right-of-way corridor of a highway. The term asset includes all components necessary for the operation of a highway, including pavements, highway bridges, tunnels, signs, ancillary structures, and other physical components of a highway.”

Asset Class – Assets with the same characteristics and function (e.g., bridges, culverts, tunnels, pavements, or guardrail) that are a subset of a group or collection of assets that serve a common function (e.g., roadway system, safety, Intelligent Transportation [IT], signs, or lighting) (23 CFR 515.5).

Asset Management – A strategic and systematic process of operating, maintaining, and improving physical assets, with a focus on both engineering and economic analysis based upon quality information, to identify a structured sequence of maintenance, preservation, repair, rehabilitation, and replacement actions that will achieve and sustain a desired state of good repair over the life cycle of the assets at minimum practicable cost (23 CFR 515.5).

Asset Management Plan – A document that describes how a State DOT will carry out asset management as defined in 23 CFR 515.5. This includes how the State DOT will make risk-based decisions from a long-term assessment of the NHS, and other public roads included in the plan at the option of the State DOT, as it relates to managing its physical assets and laying out a set of investment strategies to address the condition and system performance gaps. This document describes how the highway network system will be managed to achieve State DOT targets for asset condition and system performance effectiveness while managing the risks, in a financially responsible manner, at a minimum practicable cost over the life cycle of its assets. The term asset management plan under this part is the risk-based asset management plan that is required under 23 U.S.C. 119(e) and is intended to carry out asset management as defined in 23 U.S.C. 101(a)(2); (23 CFR 515.5).

Benefit-Cost – A comparison analysis of the economic benefit of an investment to its cost. The benefit-cost analysis includes all costs and benefits to both the agency and the users of the facility over an appropriate life-cycle period. Benefit-cost can be applied for prioritizing projects, evaluating the benefits and costs of all projects in a program, and determining program tradeoffs.

⁶ Unless specified otherwise, all definitions come from the AASHTO Pavement Management Guide (2012) by the American Association of State Highway and Transportation Officials, Washington, D.C. Used with permission.

Condition – A measure of the physical state of an asset as affected by deterioration and past maintenance and repair.

Data – Measurements (or observations) that represent a qualitative or quantitative attribute of a variable or set of variables.

Data Integration – Process of sharing data from one source among multiple applications, or of merging data from multiple sources for use by a single application.

Decision Support – The use of information (e.g., from management systems, other analytic tools, or estimates and studies by staff) to help understand the consequences of decisions.

Geographic Information System (GIS) – A tool to organize geographically-based data, create maps, and perform spatial analysis.

Integration – Combining of data or results from multiple systems.

Inventory – A compilation of the agency’s infrastructure assets, relevant characteristics (e.g., count or quantity, location, size, functional classification, traffic usage), and depending on agency practice, may include condition or performance data.

Investment Analysis – System or process that provides general guidance on predicting the performance of one or more assets within a specified budget level.

Life-Cycle Planning – A process to estimate the cost of managing an asset class, or asset sub-group over its whole life with consideration for minimizing cost while preserving or improving the condition (23CFR515.5).

Linear Referencing System (LRS) – Protocol for locating features on a highway system. The LRS enables mapping and locating asset condition, performance measures, traffic characteristics, crashes, and performance of work activities.

Maintenance – Activities that enable a transportation system to continue to perform at its intended level; comprises a range of services in preservation, cleaning, replacing work or failed components, periodic or unscheduled repairs and upkeep, motorist services (e.g., incident response, hazardous materials response), snow and ice control, and servicing of traffic devices and aids; does not add to structural or operational capacity of an existing facility.

Monitoring – Collecting and processing condition and performance data and related data (e.g., traffic usage) to understand the current status of the transportation system, identify problem areas, gauge improvements resulting from the investments, and track progress toward performance targets; provides a feedback mechanism for resource allocation and utilization decisions.

Need – Work required to help attain a policy objective or performance target, or to address a problem or deficiency.

Network – A system of assets to provide transportation services to customers.

Network-Level – The most common level at which pavement management decisions are made.

Network-level decisions typically involve choices about how to use available funding across the entire road network. Other decision levels include project and strategic levels.

Optimal – The preferred or best option based on specified criteria.

Optimization – A process for determining the best available value (e.g., cost, performance life) within a given set of constraints.

Pavement Management – A set of tools or methods that can assist decision-makers in finding cost-effective strategies for providing, evaluating, and maintaining pavements in a serviceable condition.

Pavement Management Guide – An AASHTO publication⁷ (2012) to introduce common concepts and practices used in pavement management.

Pavement Management System – A computerized tool used to assist decision-makers in finding cost-effective strategies for providing, evaluating, and maintaining pavements in a serviceable condition.

Performance Measure – An indicator, preferably quantitative, of service provided by the transportation system to users; the service may be gauged in several ways (e.g., quality of ride, efficiency and safety of traffic movements, services at rest areas, quality of system condition).

Performance Target – Threshold value of a performance measure.

Performance-Based – Characteristic of an asset that reflects its functionality or its serviceability as perceived by transportation users; often related to condition.

Preservation – Actions to prevent or correct deterioration of an asset to extend its useful life; does not entail structural or operational improvement of an existing asset beyond its originally-designed strength or capacity.

Preventive Maintenance – Proactive approach that applies maintenance treatments while the asset is still in good condition; extends asset life by preventing the onset or growth (e.g., propagation) of distress.

Program – A set of projects of similar work type (e.g., pavement rehabilitation) or serving a similar objective (e.g., to improve mobility or safety).

⁷ <https://store.transportation.org/Item/CollectionDetail?ID=117>

Project-Level – One of the three decision levels used in pavement management (with network and strategic levels). At the project level, very detailed information on a small subset of the network is used to design the appropriate treatment.

Project Prioritization – A process for comparing and ranking projects according to cost, benefit, or other performance standards.

Rehabilitation – Project to perform structural repair or capacity, operations, or safety improvements of an existing asset.

Resilience – The term "resilience", with respect to a project, means a project with the ability to anticipate, prepare for, or adapt to conditions or withstand, respond to, or recover rapidly from disruptions,, including the ability: (A)(i) to resist hazards or withstand impacts from weather events and natural disasters; or (ii) to reduce the magnitude or duration of impacts of a disruptive weather event or natural disaster on a project; and (B) to have the absorptive capacity, adaptive capacity, and recoverability to decrease project vulnerability to weather events or other natural disasters. (23 U.S.C. 101(a)(24))

Risk – The positive or negative effects of uncertainty or variability upon agency objectives. (23 CFR 515.5).

Risk Management – The processes and framework for managing potential risks, including identifying, analyzing, evaluating, and addressing the risks to assets and system performance. (23 CFR 515.5).

Stakeholders – A person, group, or organization that affects or can be affected by an agency's actions.

Strategic-Level – One of three decision levels used in pavement management (with network and project levels). Strategic decisions typically include policy and investment decisions made by upper-level management.

Tradeoff Analysis – Comparisons of alternative solutions, particularly involving consequences of reallocating funds between programs.

Work Type – Initial construction, maintenance, preservation, rehabilitation, and reconstruction (23 CFR 515.5)

APPENDIX B – PRIORITIZED ACTION ITEMS

The final stakeholder outreach session provided an opportunity for participants to establish priorities for addressing gaps using an online ranking tool. For most action categories, participants were asked to rank the importance of an item using a 0 to 5 scale, with a 5 representing the highest priority. Since the final list of action items was not available at the time the ranking was conducted, not all action items were ranked. However, the rankings provide insight into the urgency with which some topics should be addressed, and the implementation approach suggested in Section 4. A summary of the top stakeholder rankings in each action category is provided here. These suggested action items are presented as actions, that, if completed, would advance the state of the practice. No commitments to funding the suggestions contained in the *Roadmap* are implied by the FHWA or any other agency, and the relative prioritization or ranking of the action items do not reflect the views of the FHWA or any other agency.

TOP DATA COLLECTION TOPICS

The highest priority data collection topics identified during the final stakeholder outreach session are presented in ranked order.

Top Data Collection Actions to Be Addressed	Action Item Statement Number(s)	Average Rating	Percent Rated ≥ 4
Understanding what can be done with available data	1A, 1G, 10A	4.0	69%
Conducting structural testing on the network	1B, 1G, 2D, 8A, 14D	3.7	63%
Demonstrating the value of structural data	1G, 2E, 8B, 10C	3.6	61%
Improving existing methods of data collection	1D, 1E, 1F, 1G, 2H	3.5	58%
Improving data timeliness	11A, 14A,	3.2	43%
Assessing what and how frequently information is desired	3A, 3C, 11B	3.2	42%
Developing more effective contracting strategies	1E, 1F, 1G	2.4	15%

TOP DATA QUALITY TOPICS

The highest priority data quality topics identified during the final stakeholder outreach session are presented in ranked order.

Top Data Quality Topics to Be Addressed	Action Item Statement Number(s)	Average Rating	Percent Rated ≥ 4
Developing standard distress definitions/criteria	2A, 2B, 2C	4.2	72%
Assessing how much data quality is appropriate	1A	3.7	59%
Improving automated image-processing techniques	1C	3.5	51%
Developing and implementing an effective DQMP	2G	3.5	58%
Quantifying the benefits of good data	2E	3.5	56%
Establishing equipment calibration sites	10B	3.4	45%
Managing changes in data due to equipment or raters	2F, 2G	3.4	48%
Understanding and using statistics (e.g., precision/bias) correctly	8A	3.2	51%

TOP NEW TECHNOLOGY TOPICS

The highest priority new technology topics identified during the final stakeholder outreach session are presented in ranked order.

Top New Technology Topics to Be Addressed	Action Item Statement Number(s)	Average Rating	Percent Rated ≥ 4
Exploring ways of processing data (e.g., AI, machine learning)	3B	3.9	69%
Establishing criteria for consistent use of new technology	14C	3.8	67%
Developing techniques for collecting more data (e.g., surface type, drainage type)	14B, 14C	3.3	56%
Developing equipment for network-level friction testing	14D	3.3	44%
Illustrating ways to use new technology	8B, 10C, 14C	3.3	44%
Developing new ways to collect existing data (e.g., crowd source data, UAS)	3B	3.1	43%
Developing a way of collecting structural data on low-volume and urban roads (no semi)	2D	2.5	20%

TOP DATA MANAGEMENT TOPICS

The highest priority data management topics identified during the final stakeholder outreach session are presented in ranked order.

Top Data Management and Analysis Topics to Be Addressed	Action Item Statement Number(s)	Average Rating	Percent Rated ≥ 4
Data integration	3E	4.2	84%
Linear referencing	3E	3.8	67%
Data governance	3E	3.2	43%
Data storage	3A, 3C, 3E	2.8	31%

TOP DATA ANALYSIS TOPICS

The highest priority data analysis topics identified during the final stakeholder outreach session are presented in ranked order.

Top Data Analysis Topics to Be Addressed	Action Item Statement Number(s)	Average Rating	Percent Rated ≥ 4
Spatial and temporal data analysis	2F, 2G, 8A	3.9	69%
Data mining to get more out of existing data	3B, 3E, 8A, 8B	3.7	69%
Analysis of TSDD (structural) data	5B, 8B	3.3	51%
Rolling up data at the regional level	3E, 8A	3.0	35%
BIM/CIM to populate data	3D	2.1	15%

TOP PAVEMENT PERFORMANCE MODELING TOPICS

The highest priority pavement performance modeling topics identified during the final stakeholder outreach session are presented in ranked order.

Top Pavement Performance Modeling Topics to Be Addressed	Action Item Statement Number(s)	Average Rating	Percent Rated ≥ 4
Developing effective models (e.g., how to)	4D, 4E, 4F, 10A	4.1	75%
Determining the reasonableness of models	4E, 4F	3.9	70%
Identifying statistical tests to evaluate models	4E	3.6	62%
Calibrating pavement design models	4E	3.6	52%
Identifying when models should be updated	4E	3.5	58%
Incorporating risk and uncertainty into models	4C	3.4	50%
Incorporating changes in design, traffic, and other factors into models	4C	3.4	53%
Dealing with noisy or missing data	4C	3.4	49%

TOP PAVEMENT MANAGEMENT ANALYSIS TOPICS

The highest priority pavement management analysis topics identified during the final stakeholder outreach session are presented in ranked order.

Top Pavement Management Analysis Topics to Be Addressed	Action Item Statement Number(s)	Average Rating	Percent Rated ≥ 4
How to use a feedback loop to improve decisions	6B, 6G, 6H, 10A	3.8	67%
Life cycle planning	6C, 6E, 6F, 11C	3.8	65%
Multi-objective analysis capabilities	6A, 6D, 6G	3.7	57%
Use of structural (e.g., TSDD) data in decision trees	4E, 5B	3.6	60%
Incorporating risk, resilience, and sustainability into the analysis	4B, 4E, 6A	3.5	52%
New tools to analyze data	6H, 10C, 11A, 11B, 11C, 14A, 14F	3.5	47%
Ability to use user-defined criteria in the analysis	6A	3.3	50%
How to adapt the analysis to new and varied types of data	4E	3.2	42%
Consideration of new variables in the analysis	5B, 6A, 6G	3.0	37%
Strategies to help decide when new software is beneficial	6G	2.6	21%
Getting contractor assistance to help with analyses	11C, 13B	2.4	28%

TOP PERFORMANCE MANAGEMENT TOPICS

The highest priority performance management topics identified during the final stakeholder outreach session are presented in ranked order.

Top Performance Management Topics to Be Addressed	Action Item Statement Number(s)	Average Rating	Percent Rated ≥ 4
Developing performance measures for the use of pavement management suggestions	7A, 7B	3.9	70%
Addressing differences between agency and Federal performance measures	7C	3.9	70%
Setting data-driven targets using agency performance data	7A, 7B, 7D	3.7	63%
Creating and using leading performance measures (not lagging)	8B, 15A	3.7	58%
Developing effective measures for urban settings	7B	3.6	60%
Developing performance measures for structural data	8A, 8B	3.5	49%
Setting targets using Federal performance measures	7A, 7C, 7D	3.1	43%
Developing non-traditional measures (e.g., complete streets, social equity)	7B, 7D, 15B	2.6	23%

TOP ISSUES RELATED TO PAVEMENT MANAGEMENT OUTPUT USE

The highest priority pavement management output topics identified during the final outreach session are presented in ranked order.

Top Pavement Management Output Topics to Be Addressed	Action Item Statement Number(s)	Average Rating	Percent Rated \geq 4
Getting the agency to use the output for more than just reporting condition	8A, 8B, 8G, 12A, 12B	4.3	84%
Communicating impacts of different funding or treatment strategies more effectively	12A, 12B	4.2	76%
Demonstrating the cost-effectiveness of preservation treatments	5A	4.2	75%
Seeing how pavement management improved agency decisions	10C, 12A	4.1	80%
Broadening the use of pavement management throughout the agency	4E, 6A, 6D, 6E, 6F, 6G, 13B	3.9	63%
Training elected officials on their role in cost-effectively managing a pavement network	12A, 12B, 13A	3.8	67%
Training the public on pavement management concepts to build buy-in at the local level	12A, 12B	3.6	53%
Reporting pavement management outputs to satisfy the FHWA's consistency determination	6B, 6G, 6H	3.3	46%

MOST EFFECTIVE WORKFORCE DEVELOPMENT ACTIVITIES

The most effective workforce development activities identified during the final stakeholder outreach session are presented in ranked order.

Most Effective Workforce Development Activities	Average Rating	Percent Rated \geq 4
Peer exchanges	4.1	71%
Pooled fund studies	3.8	67%
Best practice summaries	3.8	61%
Regional workshops	3.6	56%
Demonstration projects	3.5	54%
In-person training courses	3.5	48%
Conferences	3.4	50%
Webinars	3.2	45%
Virtual training courses	3.2	45%
Deployment documents and reports	3.1	38%
Online user's group	3.0	36%
Videos	2.9	33%

TOP TECHNICAL DEPLOYMENT TOPICS

Participants at the final stakeholder outreach session were presented with 45 technical deployment topics and asked to pick the five most necessary topics. The results are presented in ranked order.

Top Technical Deployment Topics to Be Addressed	Action Item Statement Number(s)	Average Rating	Percent Rated ≥ 4
Data quality	1G, 2G	4.4	84%
Data analysis	1G, 4E, 5B	4.3	84%
Project selection and use of PMS results	6B, 6G, 10A, 12A, 12B, 15B	4.3	83%
Performance modeling and analysis	4E, 4F, 6G, 8B, 10A, 14F	4.3	79%
Data collection practices	1G, 2G, 2H, 10B	3.8	66%
Treatment rules and impacts	5B, 6B, 15B	3.7	53%
Performance measures and target setting	7C, 7D, 15A, 15B	3.6	68%
Data management	3E, 10A, 14C	3.5	51%
New technology	1C, 10D, 10E, 14C	3.5	49%
Organizational effectiveness	8A, 9C, 13A, 13B	3.3	48%
Workforce development	8A, 8C, 8D, 8E, 8F, 8G, 9A, 9B, 10F, 14F	3.2	37%
Workforce transitions	9C, 10C	2.9	30%

BIGGEST IMPACT ON IMPROVING AN AGENCY'S PAVEMENT MANAGEMENT PROGRAM

According to stakeholders who participated in the final outreach session, these are activities that would have the most substantial impact on improving their pavement management programs, in ranked order.

Actions Having the Biggest Impact on Pavement Management in Participating Agencies	Action Item Statement Number(s)	Average Rating	Percent Rated ≥ 4
Improving data reliability	1A, 1C, 2B, 2C 2D 2F, 2G, 8A, 10B	4.1	77%
Having evidence of the benefits to consistent funding levels	2E, 13A	4.0	77%
Raising the profile of pavement management in the organization	6G, 8G	4.0	77%
Documenting consistent operating procedures	10A	4.0	63%
Enhancing analysis capabilities with new or improved tools	4F, 6H, 10A, 11A, 11B, 11C, 14A, 14B, 14D, 14E	3.9	69%
Overcoming agency silos	13B	3.9	69%
Building the team's existing skill set	8A, 8B, 8C, 8D, 8E, 8F, 8G, 9A, 9B, 9D	3.7	63%
Adding different types of skills to the team (e.g., data analytics, statisticians)	8A, 13B	3.7	61%
Having a succession plan	10A, 10C, 13B	3.6	55%
Improving the rate at which technology is adopted	10C, 10D, 10E, 10F	3.5	54%

IMPORTANCE OF SUGGESTIONS FOR ADVANCING PAVEMENT MANAGEMENT PRACTICES

A list of suggestions for advancing pavement management practices globally were presented to the participants at the last stakeholder outreach session. The responses are presented in ranked order.

Most Important Suggestions For Advancing Pavement Management Practices	Action Item Statement Number(s)	Average Rating	Percent Rated ≥ 4
Developing templates for documenting pavement management practices	9C	3.7	54%
Establishing a portal or resource center for sharing pavement management information and practices	9A, 9B, 12B	3.6	66%
Hosting a national technology rodeo where agencies share examples of how technology is being used	10C	3.6	60%
Conducting pilot studies to apply new concepts	4B, 4C, 5A, 6A, 6C, 6E, 10C	3.5	52%
Creating publicly available software tools to supplement existing PMS capabilities in performance modeling, communicating results, and so on	4F, 11A, 11B, 11C, 14A	3.4	53%
Launching more pooled fund studies to address common demands	2A, 2B, 2D, 3A, 11A	3.4	49%
Developing an onsite technical assistance program to help agencies struggling in a certain area	10A, 10C, 10D, 10E 10F	3.4	42%
Creating an update, online (searchable) version of the AASHTO Pavement Management Guide to reflect new technology and practices	9B	3.3	52%
Creating modifiable presentation materials for communicating pavement management results	12A, 12B	3.3	49%
Creating an equipment loan program or program to test new technology	10D, 10E	3.3	43%

MOST IMPORTANT LOCAL ISSUES

The local agencies participating in the last stakeholder outreach session were asked to prioritize a list of items to reflect their important in advancing local pavement management practices. The results are presented in ranked order.

Top Local Issues to Be Addressed	Action Item Statement Number(s)	Average Rating	Percent Rated ≥ 4
Building an understanding of the importance of infrastructure preservation among elected officials	5A, 12A, 12B, 13A	4.2	76%
Developing consistent criteria for distress using automated data collection procedures	1C, 2B, 2C, 2D	3.9	72%
Developing more effective pavement performance measures in urban conditions	6A, 6D	3.9	68%
Improving rater consistency and data quality	2F, 2G, 2H	3.7	62%
Guiding the transition from manual to automated surveys	1A, 2F, 2G	3.6	59%
Creating modifiable presentation materials for communicating pavement management results	12A, 12B	3.3	49%
Adding other assets to the pavement management analysis	1G, 6A, 6D	3.2	38%
Expanding the availability of training through LTAP and other sources	9A, 9B, 9C, 9D	3.1	44%
Considering a broader range of factors in the analysis (e.g., sustainability, social equity, resilience)	6A, 6D	3.1	31%
Developing procedures for analyzing other models of travel in the analysis	6D	2.7	18%

APPENDIX C – SUGGESTED ACTION ITEMS

This appendix contains suggested action item statements developed through a collaborative process with a variety of pavement management stakeholders. In some cases, the stakeholders used words such as “recommendations” or “guidelines” or “guidance.” In these statements, these terms do not imply Federal guidance from the FHWA or recommendations to the FHWA. These statements are not a commitment or direction from the FHWA of resources toward the FHWA’s overall research program. The contents of the action item statements, including any references to and interpretations of Federal or other requirements, discussions of acceptable or predominant practices, and opinions about how research products may be used to meet Federal requirements, solely reflect the authors’ views and are not intended to reflect the views of the FHWA.

The tables below summarize each of the 72 action items by the type of work suggested (e.g., research, deployment). This organization allows cross-cutting actions that have the potential to impact the goals of more than one theme to be identified. It also allows the identification of suggestions specific to locals and/or academics. The table is followed by more complete descriptions of the work to provide researchers and administrators the information necessary to fund the activities. These descriptions can serve as the basis for obligating funding, developing proposal requests, or supporting other activities necessary for the *Roadmap*’s implementation. These suggested action items are presented as actions, that, if completed, would advance the state of the practice of pavement management. No commitments to funding the suggestions contained in the *Roadmap* are implied by the FHWA or any other agency.

The action items are organized into the following categories:

- Research
- Deployment
- Technical Assistance
- Syntheses
- Peer Exchanges
- Training
- Case Studies
- Tool Development

Research

A total of 28 research action items were identified. Of the 28 action items, 13 were short and 15 were long-term activities. The short-term actions total an estimated \$4.725 million and the long-term actions total \$6.275 million, resulting in a total estimated cost of \$11 million.

Action Item Number	Action Item Description	Short (S) or Long (L) Term	Relevant Themes				Local or Academic
			1	2	3	4	
1A	Conduct research to determine the impact of survey extent, frequency, precision, and other data quality issues on predicted conditions and project suggestions, including the cost-benefit of data quality efforts & the consequences of poor data. Develop a Data Collection Playbook on how to apply the findings at the Federal, State, and local levels	L	X				Local
1B	Evaluate the feasibility and cost-effectiveness of incorporating friction testing, structural deflection, Right of Way (ROW) imaging, and asset takeoff into existing network-level survey processes	L	X				
1C	Improve 3D data collection & interpretation technologies to enable automated identification of a broader range of pavement distress with improved consistency on both asphalt & concrete pavement	S	X				
2A	Develop methods for characterizing pavement surface characteristics that use a combination of existing and new techniques	L	X			X	
2B	Develop consistent nonregulatory distress definitions and criteria using automated data collection procedures	S	X				
2C	Develop consistent nonregulatory criteria for rutting certification and verification	S	X				
2D	Develop consistent nonregulatory criteria for network-level pavement structural health assessments	L	X				
2E	Establish a framework for documenting the benefits of good data, pilot the framework, and promote the findings	L	X				
3A	Conduct a study on cost-effective methods of storing large amounts of data over time, including suggestions for archiving data	S	X				
3B	Develop and pilot a methodology for using artificial intelligence, machine learning, citizen, and data science applications to improve the reliability and timeliness of pavement management data	L	X				
4A	Investigate and summarize the impact of using pre-treatment and material properties in pavement performance models	S		X			
4B	Develop and pilot a framework for the consideration of extreme weather (both current and future), traffic variability, environmental sustainability, and other risk factors in pavement performance modeling	S		X			

Action Item Number	Action Item Description	Short (S) or Long (L) Term	Relevant Themes				Local or Academic
			1	2	3	4	
4C	Develop and pilot pavement performance modeling techniques that a) account for “noisy data” and changes in design, traffic, and other variables and b) explain how to deal with outliers & missing data	L		X			
5A	Develop and pilot a methodology to quantify the impact and performance of preventive maintenance activities using readily available pavement management data	S		X			
6A	Develop and pilot a framework for the consideration of factors such as social equity, sustainability, and resilience in a pavement management analysis	S		X			
6C	Develop and pilot a framework for integrating maintenance data into pavement management and promoting the use of pavement management data for maintenance planning	L		X	X		
6D	Develop guidelines for accounting for other modes of travel (e.g., pedestrians, bikes, and scooters) in developing pavement management project suggestions	S		X			Local
6E	Develop and pilot a framework for integrating construction costs and life cycle assessments (LCAs) into pavement management	L		X			
7A	Identify strategies for addressing the reporting, target setting, and analysis implications of the 0.1-mile Federal requirements (23 CFR 490.309)	S		X			Local
7B	Summarize the use of performance measures to support pavement management in urban areas and develop strategies on using pavement performance measures effectively in an urban environment	L		X			
9A	Identify feasible strategies to enhance local access to pavement management training materials	S			X		Local
9B	Develop an online, searchable Pavement Management Guide to address current topics	S			X		Local
9C	Develop and make available templates for documenting pavement management models, treatment rules, processes, and procedures	S			X		
14A	Develop automated approaches for processing and analyzing pavement management data	L				X	
14B	Develop technology to assess drainage conditions with minimal manual involvement	L				X	
14D	Develop equipment to assess pavement structural condition on rigid pavements and on low-level roads where semis are not a viable option	L				X	Local
14E	Develop equipment for continuous friction measurements	L				X	
14F	Develop strategies to facilitate the implementation of university research to advance pavement management	L				X	Academic

Deployment

A total of 14 deployment topics were identified. Of these 14 items, 13 were suggested as short-term activities and only 1 was a long-term activity. The short-term actions total an estimated \$3.525 million, and the long-term action was estimated at \$0.250 million, resulting in a total estimated cost of \$3.775 million.

Action Item Number	Action Item Description	Short (S) or Long (L) Term	Relevant Themes				Local or Academic
			1	2	3	4	
1G	Develop deployment materials on strategies for: <ul style="list-style-type: none"> • Contracting data collection activities • Use of TSDD data to define network structural condition • Quantifying the value of using network-level structural data in a PMS • Using GPR • Using macrotexture • Using existing equipment to collect asset inventory and condition information for curb ramps, signage, sidewalks, curb and gutter, and other information • Integrating utility information into a PMS • Streamlining data collection activities 	S	X				
2G	Develop deployment strategies for: <ul style="list-style-type: none"> • Addressing challenges with transitions in procedures and addressing differences temporally and spatially • Improving consistency between raters and/or years • Implementing automated data quality checks and processes for interim data acceptance • Using the acceptance criteria established through the FHWA Pooled Fund TPF-5(299) and (399) • Using data sampling • Certifying equipment and operators 	S	X				
2H	Develop and pilot a framework for addressing the road data deficiencies on Tribal lands	S	X				
3E	Develop deployment strategies for: <ul style="list-style-type: none"> • Integrating various data sources, including LRS issues • Storing large amounts of data • Documenting data with proper metadata 	S	X				

Action Item Number	Action Item Description	Short (S) or Long (L) Term	Relevant Themes				Local or Academic
			1	2	3	4	
4E	Develop deployment strategies for: <ul style="list-style-type: none"> • Developing performance models, including techniques for modeling with no historic data • Evaluating model reasonableness & reliability • Determining when models should be updated • Developing performance models using TSDD data • Incorporating risks into models, including current and future environmental risks • Evaluating the impact of risk on project conditions • Using models to calibrate pavement design procedures • Using data science to evaluate trends & treatment effectiveness • Documenting models 	S		X			
5B	Develop deployment strategies for: <ul style="list-style-type: none"> • Incorporating maintenance & preventive maintenance treatments into a PMS • Incorporating TSDD results into decision trees • Determining conditions under which treatments are viable (e.g., proactive maintenance, low or high preservation, minor or major rehabilitation) • Considering variations in existing conditions when defining the impact of preventive maintenance treatments • Documenting treatment rules 	S		X			
6B	Develop deployment materials on aligning pavement management suggestions with programmed projects	S		X			
6G	Develop deployment strategies for: <ul style="list-style-type: none"> • Establishing an effective feedback loop • Determining whether new software tools would be beneficial • Using PMS results in a multi-objective project selection process • Incorporating risk & resilience into an analysis • Selecting projects that improve agency resilience • Evaluating the impact that new developments have on conditions when assessing future funding demands • Defining “backlog” 	S		X			
7D	Develop deployment strategies for data-driven target setting	S		X			
12A	Develop deployment strategies on presenting pavement management outputs and communicating the long-term impact of deferred investment	S			X		
13B	Develop deployment strategies for overcoming organizational silos impacting pavement management, recognizing the benefits associated with cross training, multi-discipline collaboration, and succession planning	S			X		

Action Item Number	Action Item Description	Short (S) or Long (L) Term	Relevant Themes				Local or Academic
			1	2	3	4	
14C	Establish deployment strategies for: <ul style="list-style-type: none"> • Using data from crowdsourced data, connected and automated vehicles, unmanned aircraft systems, and other automated technology to support pavement management analysis • Documenting precision/bias statements that can be put into practice • Using new technology in concert with traditional data collection practices • Replacing outdated technology with proven new technology • Applying the Technology Readiness Level Guidebook published by NASA to evaluate whether new technology is ready to be implemented 	S				X	
15A	Develop and pilot deployment materials on using leading measures, such as structural data, to influence pavement management decisions	S				X	
15B	Develop and pilot deployment materials on the use of non-traditional performance measures (e.g., crash reduction, complete streets components, Americans with Disabilities Act (ADA)-compliant facilities, other travel models, and social equity) to support project and treatment selection processes	L				X	Local

Technical Assistance

There were five suggestions for technical assistance identified. Of the 5 items, 2 were short and 3 were long-term activities. The short-term actions total an estimated \$1.0 million, and the long-term actions total \$7.9 million, resulting in a total estimated cost of \$8.9 million.

Action Item Number	Action Item Description	Short (S) or Long (L) Term	Relevant Themes				Local or Academic
			1	2	3	4	
10A	Pilot and implement a technical assistance program on: <ul style="list-style-type: none"> • Data management, data quality, & other data-related issues • Pavement performance modeling and use of a feedback loop • Documenting pavement management practices 	S	X	X	X		
10B	Develop a National Equipment Certification Center	L	X		X		
10C	Conduct pilot programs to demonstrate: <ul style="list-style-type: none"> • The use of new technology • Benefits to using the next generation performance measures • Return on investment from using GPR and TSDD data • Strategies for using PMS data to support multi-objective decision analysis • The conversion of research results into practice • Use of PMS data to support maintenance scheduling and planning • Successful transition strategies (such as recruiting, retention, training, and promotion) 	L		X	X	X	
10D	Develop an equipment loan program to enable agencies an opportunity to test new technology	S			X	X	
10E	Develop a program to support new technology trials	L			X	X	

Synthesis

There were four synthesis topics identified, with all of them suggested as short-term activities. The cost for these syntheses is estimated to be \$200,000.

Action Item Number	Action Item Description	Short (S) or Long (L) Term	Relevant Themes				Local or Academic
			1	2	3	4	
1D	Synthesize practices regarding the collection of inventory and condition data on lower-level roadways, shoulders, & ramps, and the benefits associated with collecting this information	S	X				
1E	Synthesize successful practices on contracting for pavement management data collection	S	X				Local
3C	Synthesize agency policies on data storage, including any limitations imposed by oversight agencies	S	X				
6H	Summarize effective data visualization and communication efforts to support project selection and scoping	S		X			Local

Peer Exchange

Six short-term peer exchange topics were identified at an estimated cost of \$450,000.

Action Item Number	Action Item Description	Short (S) or Long (L) Term	Relevant Themes				Local or Academic
			1	2	3	4	
1F	Conduct a peer exchange to discuss strategies for addressing contracting issues associated with data collection activities and improving the timeliness of survey data	S	X				Local
2F	Conduct a peer exchange to discuss how agencies are a) addressing challenges in data collection equipment transitions, b) reconciling differences temporally & spatially, c) verifying cracking, transverse profile, & faulting values, d) developing stability in ratings when protocols/practices change, e) preparing & following an effective DQMP, establishing data acceptance criteria	S	X				Local
3D	Conduct a peer exchange to address the use of BIM/CIM and e-construction data to populate pavement histories	S	X	X			
4D	Conduct a peer exchange to discuss techniques and practices associated with pavement performance modeling	S		X			
6F	Conduct a peer exchange to discuss a) how a PMS is used to support life cycle planning, b) typical matches between analysis results & projects, and c) use of PMS data to support other departments	S		X			
7C	Conduct a peer exchange to discuss a) how agencies are explaining & analyzing differences in State and Federal measures, b) strategies to improve Federal measures, and c) how to use pavement management data to set performance targets	S		X			

Training

A total of 10 action items in the training category were identified. Of the 10 action items, 5 were short and 5 were long-term activities. The short-term actions total an estimated \$3.0 million and the long-term actions total \$1.2 million, resulting in a total estimated cost of \$4.2 million.

Action Item Number	Action Item Description	Short (S) or Long (L) Term	Relevant Themes				Local or Academic
			1	2	3	4	
8A	Develop training on: <ul style="list-style-type: none"> • Pavement data collection strategies • Basic statistics • Data quality management plans and how to use them • Equipment calibration and certification practices • Other data quality topics, including data sampling and reviewing processes, error resolution, pre-processing techniques to address data issues, rater certification • Data science applications for pavement management • SQL and other database programming skills • Pavement performance modeling, including data elements, model types, & statistical acceptance • Using structure data and other information to support project & treatment selection • Building pavement management champions 	S	X		X		
8B	Conduct workshops to share deployment materials on: <ul style="list-style-type: none"> • How to use GPR data for project selection • Use of TSDD data in decision trees and performance models • Data integration • Using pavement management for life cycle planning • The development and use of leading performance measures 	S	X		X		
8C	Develop and implement a Peer-to-Peer training program	L			X		
8D	Redesign the FHWA's PMS User's Group to focus more on training	S			X		
8E	Conduct book club sessions on the updated Pavement Management Guide when finished	L			X		
8F	Conduct workshops on the updated Pavement Management Guide at conferences	L			X		
8G	Incorporate updated training materials into a Pavement Management Leadership Academy to build skills & raise pavement management's profile	L			X		
9D	Create on-the-job and just-in-time training materials	S			X		
10F	Develop and support an equipment & new technology demonstration program at the university level to train students	L			X	X	Academic
12B	Create sharable materials that convey pavement management messaging for the public that can be placed on an agency's website	S			X		Local

Case Studies

Development of one short-term case study was estimated to cost \$150,000.

Action Item Number	Action Item Description	Short (S) or Long (L) Term	Relevant Themes				Local or Academic
			1	2	3	4	
13A	Document success stories where consistent funding for pavement management updates has led to improvements in network conditions and contrast this with agencies where funding has not been consistent	S			X		Local

Tool Development

Four action items suggest the development of software tools. Two are short-term suggestions and the other two are long-term activities. The short-term actions are estimated to cost \$1.05 million, and the long-term actions total \$500,000, resulting in a total estimated cost of \$1.55 million.

Action Item Number	Action Item Description	Short (S) or Long (L) Term	Relevant Themes				Local or Academic
			1	2	3	4	
4F	Develop a tool to predict pavement performance based on LTPP data (default) or using a State’s pavement management data	S		X			
11A	Develop a consistent, automated data checking tool to evaluate submittals by data vendors in accordance with the DQMP	S	X				Local
11B	Create software for accessing images from data collection efforts beyond the 5 years available from vendors	L	X				
11C	Support vendor software modifications to better enable an LCP analysis and the use of next -generation pavement performance measures	L		X			

RESEARCH ACTION ITEMS

Note: These suggested action items are presented as actions, that, if completed, would advance the state of the practice of pavement management. No commitments to funding the suggestions contained in the *Roadmap* are implied by the FHWA or any other agency.

1A: Develop a Data Collection Playbook to Improve Data Collection Practices

Category of Work (Research, Training, Deployment, etc.): Research

Short- or Long-Term? Long-term

Description/Items to Be Addressed

Conduct research to determine the impact of survey extent, frequency, precision, & other data quality issues on predicted conditions & project suggestions, including the cost-benefit of data quality efforts & the consequences of poor data. Develop a Data Collection Playbook on how to apply the findings at the Federal, State, & local levels.

Primary Objectives

1. Develop materials on data collection practices to improve data quality, including an effective Data Quality Management Plan.
2. Document the cost-effectiveness of data quality efforts and the consequences of poor data.
3. Develop implementation strategies.

Proposed Research Activities (work steps)

Working in conjunction with TPF-5(299)/(399), conduct the following activities:

- Develop materials on preparing and using an effective Data Quality Management Plan.
- Design a pilot study to evaluate the cost and benefits associated with different quality measures, including different amounts of data, adherence to a Data Quality Management Plan, the use of pre-collection testing and certification, and the use of acceptance testing.
- Conduct the pilot study.
- Analyze differences in data quality costs and benefits from the pilot study, including impacts on pavement management decisions.
- Develop a Data Collection Playbook based on the findings.
- Develop a final report and implementation plan.

Desired Products

- Data Collection Playbook.
- Final Report.
- Implementation Plan.
- Technical Brief.
- Webinar.
- Training Materials.

Estimated Timeframe and Cost

Cost: \$500,000

Duration: 36 months

1B: Evaluate the Cost-Effectiveness of Friction, Structural, and ROW Imaging

Category of Work (Research, Training, Deployment, etc.): Research

Short- or Long-Term? Long-term

Description/Items to Be Addressed

Evaluate the feasibility and cost-effectiveness of incorporating friction testing, structural deflection, right-of-way (ROW) imaging, and asset takeoff into existing network-level survey processes.

Primary Objectives

1. Investigate the feasibility to using existing technology to support pavement management decisions.
2. Quantify the benefits and costs associated with the use of existing technology.
3. Document the results.

Proposed Research Activities (work steps)

Technology exists to support pavement management through network-level friction testing, structural deflection testing, and ROW imaging for building asset inventories. Agencies considering the use of these technologies do not have easy access to information about how they can be used, what benefits are realized, and what resources are needed. This research will provide the information desired by transportation agencies to make informed decisions about the use of these types of technology through the completion of the following activities:

- Identify the potential uses for data obtained from network-level friction testing, structural deflection testing, and ROW imaging.
- Identify considerations and/or limitations to the use of these technologies.
- Summarize the benefits and costs associated with the use of these technologies.
- Summarize the results in a final report.
- Present the results in a webinar.

Desired Products

- Final report documenting the benefits, costs, and limitations to using existing data collection technology to support pavement management.
- Webinar presenting the findings.

Estimated Timeframe and Cost

Cost: \$150,000

Duration: 18 months

1C: Improve Automated Distress ID on Both Asphalt and Concrete Pavement

Category of Work (Research, Training, Deployment, etc.): Research

Short- or Long-Term? Short-term

Description/Items to Be Addressed

Improve 3D data collection & interpretation technologies to enable automated identification of a broader range of pavement distress with improved consistency on both asphalt & concrete pavement.

Primary Objectives

1. Improve processes for automatically identifying a broad range of distress on both asphalt and concrete pavement.
2. Improve the accuracy of distress interpretation from the automated processes.
3. Develop suggestions for putting the findings into practice.

Proposed Research Activities (work steps)

The use of automated equipment to collection pavement distress information is becoming more common. Distress images can be processed using either automated or semi-automated processes. While automated processes have the potential to reduce the amount of time needed to extract distress information, there are some distress types that are difficult to discern using this technology. This study explores the use of new technology to improve distress identification capabilities. The results of this study will improve the accuracy and the timeliness of data collection and processing activities through the following activities:

- Summarize gaps between current and desired conditions in terms of distress collection and interpretation.
- Identify potential technology to address the gaps.
- Explore the feasibility of new technology to enhance distress interpretation capabilities on both asphalt and concrete pavement.
- Develop a prototype to demonstrate the feasibility of the new technology.
- Document the findings.

Desired Products

- Prototype tool to use for distress interpretation.
- Documentation describing the use of new technology to support automated distress interpretation.

Estimated Timeframe and Cost

Cost: \$750,000

Duration: 36 months

2A: Develop Surface Characterization Methods Using Existing and New Technology

Category of Work (Research, Training, Deployment, etc.): Research

Short- or Long-Term? Long-term

Description/Items to Be Addressed

Develop methods for characterizing pavement surface characteristics that use a combination of existing (e.g., advance image processing & machine learning techniques) and new (e.g., CAVs, smartphone sensor data, etc.) technology.

Primary Objectives

1. Investigate existing and new technology that can provide additional surface characterization information, such as pavement surface type (e.g., surface treatment, open-graded friction course, stone matrix asphalt), location and condition of drainage structures, and location of ancillary assets viewable from the right of way that will advance the state of practice in pavement management.

Proposed Research Activities (work steps)

The availability of additional data types and sources can help expand data collection to more routes within an agency's highway network and provide additional information to improve pavement management analyses. Several existing and emerging technologies (such as connected and autonomous vehicles, smartphone sensor data, crowdsourced data, etc.) might help to bridge gaps in this area. The research objectives will be achieved through the completion of the following activities:

- Conduct a literature search of recent research related to additional types of data that can help advance the state of practice in pavement management.
- Document the benefits of collecting additional data that is not typically used in pavement management today.
- Identify approaches for using data from existing and emerging technologies for use in pavement management and document the feasibility and usefulness of each approach.
- Demonstrate the applicability of various emerging technologies through small-scale pilot studies.
- Develop deployment materials for using the new technology effectively.
- Develop deployment materials for modifying pavement management systems to incorporate data from emerging technologies.

Desired Products

- Deployment materials for using available technologies and methodologies that can provide additional data not typically used in pavement management today, the benefits and limitations associated with each technology, and the types of data that can be provided.
- Implementation plan.
- Suggestions on incorporating data from existing and emerging technologies into a PMS.

Estimated Timeframe and Cost

Cost: \$350,000

Duration: 18 months

2B: Develop Consistent Nonregulatory Distress Definitions and Criteria Using Automated Data Collection Procedures

Category of Work (Research, Training, Deployment, etc.): Research

Short- or Long-Term? Short-term

Description/Items to Be Addressed

Develop consistent nonregulatory distress definitions & criteria using automated data collection procedures.

Primary Objectives

1. In conjunction with TPF-5(299)/(399), develop a voluntary data dictionary for distress on jointed concrete, continuously reinforced concrete, and asphalt pavements (including multiple types of cracking, faulting, patching, raveling, punchouts, bleeding, etc.).
2. Develop a nonregulatory common language for contracting, research, and Federal reporting.
3. Develop cross correlations for different methods of defining and quantifying distress.

Proposed Research Activities (work steps)

The many definitions used by State DOTs for describing pavement condition make it difficult to exchange practices with other States and it makes Federal reporting a challenge. There are some AASHTO protocols, but these have not been widely adopted. The Distress Identification Manual for the Long-Term Pavement Performance Program (LTPP) contains standard definitions for manually collected data but has limited application for automated data collection. The research objectives will be accomplished through the following activities:

- Form an expert task group (ETG) to advise the researchers.
- Assemble a catalog of pavement distress definitions from the LTPP Distress Manual, existing criteria, Federal agencies, State DOTs, local agencies, data collection vendors, and data collection equipment manufacturers.
- Develop a Pavement Distress Catalog with the information gathered.
- Working with the ETG, determine pavement distress definitions to be included in the Pavement Distress Data Dictionary.
- Develop detailed definitions for the selected pavement distress items, quantification methods, and data collection terminology.
- Develop a final report and implementation plan.

Desired Products

- A Pavement Distress Data Dictionary
- Final report and implementation plan

Estimated Timeframe and Cost

Cost: \$400,000

Duration: 24 months

2C: Develop Consistent Nonregulatory Criteria for Rutting Certification and Verification

Category of Work (Research, Training, Deployment, etc.): Research

Short- or Long-Term? Short-term

Description/Items to Be Addressed

Develop consistent nonregulatory criteria for rutting certification & verification.

Primary Objectives

1. Identify suggestions for improving the certification and verification of equipment to measure rutting.

Proposed Research Activities (work steps)

Nonregulatory AASHTO Standard R48 presents suggested practice for determining rut depth in pavements. The FHWA has published a report (FHWA-RC-20-004) that summarizes the development of practices to calibrate, certify, and verify transverse profile equipment used to collect rut depth. Transportation agencies desire sufficient skills to determine with confidence that the data collected is accurate and the reported results are comparable to other methods. This research develops suggestions for implementing practices for the certification and verification of rut depth while also building the understanding of these measures in transportation agencies. The research objectives will be achieved through the following activities:

- Identify consistent practices for certifying and verifying rut measurements.
- Seek input from practitioners on challenges to rut depth certification and verification.
- Develop suggestions for overcoming challenges with the use of consistent practices.
- Develop workshops and other training materials to improve the understanding of procedures for certifying and verifying rut depth measures.
- Suggest an implementation plan for putting the materials into practice.

Desired Products

- Nonregulatory practices for certifying and verifying rut depth measures.
- Materials to promote the use of these practices.

Estimated Timeframe and Cost

Cost: \$150,000

Duration: 18 months

2D: Develop Consistent Nonregulatory Criteria for Network-Level Pavement Structural Health Assessments

Category of Work (Research, Training, Deployment, etc.): Research

Short- or Long-Term? Long-term

Description/Items to Be Addressed

Develop consistent nonregulatory criteria for the use of structural pavement assessment results to support pavement management decisions.

Primary Objectives

1. Identify strategies for using structural performance data in the pavement management decision process.
2. Develop a methodology for incorporating network-level structural condition data into analytical models.
3. Illustrate the benefits to using network-level structural information in pavement management.

Proposed Research Activities (work steps)

Continuous pavement deflection has been collected by several Federal and State highway agencies. However, the information is not widely used in pavement deterioration models or treatment rules. A methodology for using network-level structural data in pavement management is desired. The research objectives will be accomplished through the following activities:

- Summarize current practice in the use of network-level structural data.
- Identify potential uses for network-level structural data in pavement management.
- Develop a methodology that incorporates network-level structural data into pavement management models, including pavement performance modeling, treatment rules, and performance measures.
- Describe the benefits realized from using structural data at the network level.
- Validate the methodology in at least one State DOT.
- Summarize suggestions for using network-level structural data in pavement management.
- Conduct implementation activities to promote the use of structural data in pavement management.

Desired Products

- Methodology for using network-level structural data in pavement management.
- Implementation activities to promote the use of the results.

Estimated Timeframe and Cost

Cost: \$250,000

Duration: 24 months

2E: Establish a Framework for Estimating the Benefits to Good Data

Category of Work (Research, Training, Deployment, etc.): Research

Short- or Long-Term? Long-term

Description/Items to Be Addressed

Establish a framework for documenting the benefits of good data, pilot the framework, and publish the findings.

Primary Objectives

1. Develop a framework that practitioners can use to quantify the benefits to good data.
2. Validate the approach and document the benefits realized.
3. Promote the findings.

Proposed Research Activities (work steps)

Data-driven decisions rely on the availability of quality data to understand current conditions and to forecast future conditions under various scenarios. The collection and maintenance of pavement inventory and condition information is one of the most resource-intensive aspects to pavement management. This research will develop a framework for quantifying the benefits to quality data. This will be accomplished through the following activities:

- Conduct a literature search to investigate approaches to quantify the benefits to good data in various industries.
- Identify promising approaches for use in estimating the benefits to managing the quality of pavement management data.
- Test the promising approaches using sample data from various transportation agencies.
- Use the findings to develop a framework for estimating the benefits to good data.
- Develop simple tools to quantify the benefits to good data.
- Conduct one or more pilot studies to validate the framework.
- Document the results from the pilot studies.
- Prepare documentation explaining the framework and its use.
- Develop an implementation plan to promote the use of the research products.

Desired Products

- Framework for practitioners' use in estimating the benefits to good data.
- Simple tools for quantifying benefits.
- Implementation plan.

Estimated Timeframe and Cost

Cost: \$250,000

Duration: 24 months

3A: Evaluate Cost-Effective Methods of Storing Large Amounts of Data

Category of Work (Research, Training, Deployment, etc.): Research

Short- or Long-Term? Short-term

Description/Items to Be Addressed

Conduct a study on cost-effective methods of storing large amounts of data over time, including suggestions for archiving data.

Primary Objectives

1. Develop strategies for cost-effective ways to store large volumes of pavement management data, including suggestions for data documentation, successful data integration strategies, and unified location referencing approaches to facilitate data sharing, integration, and access.
2. Develop suggestions for setting policies on what to store and for how long.

Proposed Research Activities (work steps)

Data governance is critical to effectively managing enterprise data quality, access, and integration. With its vast amounts of data that cuts across different applications, pavement management data demands good governance. Under this study, the following work will be conducted:

- Establish a data governance framework.
- Develop criteria for standard location referencing to ensure proper data management and allow for easy integration.
- Outline a process for defining roles and responsibilities for data governance.
- Establish a framework for continuous improvement of data documentation.
- Develop materials on ensuring data quality: timeliness, completeness, accuracy, and consistency.
- Address spatial and temporal aspects of data to allow for proper management and analysis.

Desired Products

- Deployment documents with a research implementation plan.
- Nonregulatory data governance framework toolbox

Estimated Timeframe and Cost

Cost: \$750,000

Duration: 36 months

3B: Develop & Pilot Innovative Ways to Improve Data Reliability and Timeliness

Category of Work (Research, Training, Deployment, etc.): Research

Short- or Long-Term? Long-term

Description/Items to Be Addressed

Develop & pilot a methodology for using artificial intelligence (AI), machine learning, citizen & data science applications to improve the reliability and timeliness of pavement management data.

Primary Objectives

1. Develop strategies for getting more from the data that is being collected through innovative uses such as big data and data science applications.
2. Identify improvements that could be made to existing data processing and analysis techniques using new and emerging techniques such as machine learning and artificial intelligence.
3. 3. Develop strategies to justify data collection costs.
4. Determine modifications to existing PMS software that would support techniques identified.
5. Provide suggestions on using artificial intelligence and machine learning to support pavement management.

Proposed Research Activities (work steps)

Existing data collection technologies and methodologies demand extensive amounts of time to process so it is available for use. Additionally, the amount of data collected presents challenges in its use. Agencies would benefit from identifying new and emerging approaches to address these challenges and leverage advances to current practice. This research effort will involve:

- Exploring AI and knowledge discovery approaches that best fit pavement management data and applications.
- Documenting well-developed practices on data mining in State DOTs that may be applicable.
- Establishing a framework for using these techniques effectively within transportation agencies.
- Developing simple software tools to help agencies implement identified techniques.
- Developing suggestions on how to incorporate these techniques into pavement management applications.

Desired Products

- Deployment document on the use of innovative practices.
- Simple software tools to help promote the use of these techniques.
- Implementation strategies for putting the results into practice.
- Pilot study.

Estimated Timeframe and Cost

Cost: \$750,000

Duration: 36 months

4A: Investigate the Impact of Pre-Treatment Condition and Material Properties on Pavement Performance Models

Category of Work (Research, Training, Deployment, etc.): Research

Short- or Long-Term? Short-term

Description/Items to Be Addressed

Investigate and summarize the impact of using pre-treatment and material properties in pavement performance models.

Primary Objective

1. Develop methods for consideration of pre-treatment conditions and material properties in pavement performance modeling and treatment rules.

Proposed Research Activities (work steps)

Pavement preservation and rehabilitation treatments are applied to pavements with varying conditions. The type and extent of deterioration present can have a significant influence on the way a treatment performs over time. For instance, the use of a thin overlay on a pavement with structural deterioration will perform differently than its use on a pavement with only environmental cracking. Material properties have a similar effect on treatment performance. However, these factors are typically not considered in pavement performance modeling. This research explores the impact of using pre-treatment condition, material properties, and other factors in pavement performance modeling and provides suggestions for implementation. The objectives will be achieved through the following activities:

- Explore current practices regarding the availability and use of pre-treatment condition and material properties in pavement management systems.
- Identify promising practices for considering these factors in pavement management models.
- Use pavement management data to test the feasibility of the promising practices.
- Develop suggestions for how to use pre-treatment condition and material properties in pavement management models.
- Test the suggestions using data provided by several pilot agencies.
- Document the suggestions for deployment.
- Develop an implementation plan to promote the use of the findings.

Desired Products

- Suggestions on using pre-treatment condition and material properties in pavement management models.
- Implementation plan for putting the findings into practice.

Estimated Timeframe and Cost

Cost: \$250,000

Duration: 24 months

4B: Develop and Pilot a Framework for Consideration of Risk Factors in Pavement Performance Models

Category of Work (Research, Training, Deployment, etc.): Research

Short- or Long-Term? Short-term

Description/Items to Be Addressed

Develop & pilot a framework for the consideration of extreme weather (both current and future), traffic variability, environmental sustainability, and other risk factors in pavement performance modeling.

Primary Objectives

1. Develop a framework for the consideration of risk factors and vulnerabilities in pavement performance modeling.
2. Pilot the conceptual framework.
3. Provide suggestions on how to consider risk in pavement performance models.

Proposed Research Activities (work steps)

Pavements are vulnerable to failure from one-time events (e.g., flooding), systemic changes in weather patterns, or extreme changes in conditions (e.g., significant increases in traffic loading); however, these risks are not typically considered in pavement performance models. Bridge management systems have long included a method for assessing vulnerabilities in modeling. Agencies will benefit from the development of criteria for defining, evaluating, or analyzing vulnerabilities to pavements on a network basis to better address uncertainties. The research objectives will be accomplished through the following activities:

- Perform a literature review to identify current research on vulnerabilities influencing pavement performance.
- Review current tools and processes for considering risk in other transportation applications.
- Develop a conceptual framework for considering risk factors in pavement management modeling.
- Validate the conceptual model through a pilot implementation at one or more State DOTs.
- Summarize the findings and provide suggestions on how risks can be considered in the development of pavement performance models.

Desired Products

- A framework for considering risk in pavement performance models.
- Deployment materials on how the findings can be applied and the benefits to doing so.

Estimated Timeframe and Cost

Cost: \$250,000

Duration: 24 months

4C: Develop and Pilot Pavement Performance Modeling With Noisy and Missing Data

Category of Work (Research, Training, Deployment, etc.): Research

Short- or Long-Term? Long-term

Description/Items to Be Addressed

Develop & pilot pavement performance modeling techniques that a) account for “noisy data” & changes in design, traffic, and other variables and b) explain how to deal with outliers & missing data.

Primary Objective

1. Improved practices on pavement performance modeling to address common issues with pavement data.

Proposed Research Activities (work steps)

Pavement condition data varies considerably due to a variety of factors related to the type of data collected and the methods used to collect and process it. This leads to “noisy” data that makes it difficult to discern clear deterioration patterns when developing pavement performance models. Another challenge in pavement performance modeling is missing data, which can occur because of incomplete data sets. This research addresses these and other challenges that complicate the development of pavement performance models with clear, implementable suggestions. The research objective will be accomplished through the following activities:

- Survey pavement performance modeling practices in State DOTs.
- Identify factors that complicate the development of reliable models.
- Develop feasible approaches for overcoming challenges with data issues.
- Test the approaches using actual pavement data from one or more State DOTs.
- Summarize the results from the trial.
- Finalize the approaches for addressing the data challenges.
- Document the results in deployment materials.
- Develop an implementation plan for putting the findings into practice.

Desired Products

- Suggestions for addressing data issues in pavement performance modeling.
- Implementation plan.

Estimated Timeframe and Cost

Cost: \$200,000

Duration: 18 months

5A: Develop and Pilot a Methodology to Quantify the Impact of Preventive Maintenance Activities

Category of Work (Research, Training, Deployment, etc.): Research

Short- or Long-Term? Short-term

Description/Items to Be Addressed

Develop & pilot a methodology to quantify the impact and performance of preventive maintenance activities using readily available pavement management data.

Primary Objectives

1. Develop a methodology that can be easily implemented by pavement management practitioners to:
2. Quantify the cost and performance of common pavement preventive maintenance activities.
3. Identify strategies for handing preventive maintenance treatments used in a stop-gap manner.
4. Estimate the cost-effectiveness of common preventive maintenance treatments.
5. Test the methodology using pavement management data from several State DOTs.
6. Develop suggestions for implementing the methodology.

Proposed Research Activities (work steps)

Preventive maintenance treatments have an important role in reducing the long-term life-cycle cost of preserving a pavement network. However, pavement managers face challenges in configuring their pavement management systems to adequately model the cost-effectiveness of preventive maintenance treatments. This research will result in a methodology that can be adopted to address this challenge through the conduct of the following activities:

- Identify common preventive maintenance treatments to be considered in the methodology.
- Seek input from practitioners to identify challenges with incorporating preventive maintenance treatments into a pavement management analysis.
- Develop a methodology to overcome the challenges with configuring pavement management systems to consider preventive maintenance treatments in performance models, treatment rules, and treatment impact models.
- Use the methodology to demonstrate the cost-effectiveness of preventive maintenance treatments using data provided by several selected State DOTs.
- Document the methodology.
- Provide suggestions for implementing the methodology.

Desired Products

- Methodology for incorporating preventive maintenance into a pavement management system.
- Suggestions for implementing the methodology.

Estimated Timeframe and Cost

Cost: \$300,000

Duration: 30 months

6A: Develop and Pilot a Framework for Consideration of Social Equity, Sustainability, and Resilience in a Pavement Management Analysis

Category of Work (Research, Training, Deployment, etc.): Research

Short- or Long-Term? Short-term

Description/Items to Be Addressed

Develop & pilot a framework for the consideration of factors such as social equity, sustainability, & resilience in a pavement management analysis.

Primary Objectives

1. Develop a framework for the consideration of social and environmental factors in a pavement management analysis.
2. Validate the framework through a pilot study with one or more State DOTs.
3. Develop suggestions for implementing the framework.
4. Conduct implementation activities to promote the use of social and environmental factors in pavement management.

Proposed Research Activities (work steps)

Traditional pavement management analyses rely primarily on pavement condition improvements to determine the cost-effectiveness of different combinations of projects and treatments. In recent years, there has been an increased emphasis on expanding the factors considered in the analysis to include social equity, sustainability, and resilience. This research effort will provide strategies on how these factors can be considered in a pavement management analysis through the completion of the following tasks:

- Identify the social and environmental factors most useful in a pavement management analysis.
- Conduct a peer exchange with practitioners to determine how these factors influence project and treatment selection.
- Develop a framework for incorporating social and environmental factors in project and treatment selection.
- Validate the framework in one or more State DOTs and document the findings.
- Document the framework in the form of deployment materials that can be readily adopted by pavement managers.
- Conduct workshops and webinars to promote the results.

Desired Products

- Suggestions on the use of social and environmental factors in project and treatment selection decisions.
- Workshops and webinars to promote the implementation of the suggestions.

Estimated Timeframe and Cost

Cost: \$350,000

Duration: 24 months

6C: Develop and Pilot a Framework for Integrating Maintenance Data into Pavement Management

Category of Work (Research, Training, Deployment, etc.): Research

Short- or Long-Term? Long-term

Description/Items to Be Addressed

Develop & pilot a framework for integrating maintenance data into pavement management & promoting the use of pavement management data for maintenance planning.

Primary Objectives

1. Strengthen the consideration of maintenance data in a pavement management system.
2. Develop a framework for using pavement management data to support maintenance decisions regarding pavement maintenance and preventive maintenance treatments.
3. Pilot the framework.

Proposed Research Activities (work steps)

Due to differences in the way data are recorded and/or incompatibility between databases, pavement management systems often omit the consideration of maintenance impacts on pavement performance predictions. There are also often disconnects between the scheduling and planning of maintenance activities and planned capital improvements. This research seeks to strengthen the consideration of maintenance in a pavement management system and demonstrate how pavement management information can be used to support maintenance work planning. The research objectives will be accomplished through the following activities:

- Summarize current practices in the consideration of maintenance activities in pavement management and the use of pavement management project suggestions in maintenance planning.
- Identify case studies documenting well-established practices that show promise for guiding the development of the framework.
- Develop a framework that strengthens the ability to link pavement management considerations with pavement maintenance planning and scheduling activities.
- Pilot the framework in one or more State DOTs.
- Document the findings in a final report.
- Prepare suggestions for implementing the framework.

Desired Products

- Framework for strengthening the links between pavement management and maintenance.
- Suggestions on implementing the framework.

Estimated Timeframe and Cost

Cost: \$250,000

Duration: 24 months

6D: Develop Guidelines for Accounting For Other Modes of Travel in Pavement Management

Category of Work (Research, Training, Deployment, etc.): Research

Short- or Long-Term? Short-term

Description/Items to Be Addressed

Develop nonregulatory criteria for accounting for other modes of travel (e.g., pedestrians, bikes, & scooters) in developing pavement management project suggestions.

Primary Objectives

1. Develop nonregulatory criteria that explain how different transportation models can be accounted for in pavement management project suggestions.
2. Validate the criteria with one or more transportation agencies.
3. Publish suggestions for putting the criteria into practice.

Proposed Research Activities (work steps)

In addition to cars, trucks, and buses, roads and highways serve other modes of transportation, including pedestrians, bicycles, and scooters. Considerations of the criteria for these transportation models are typically addressed outside of a pavement management system. This study seeks to explore strategies for better addressing a complete set of transportation demands in pavement management project suggestions. This will be accomplished through the following activities:

- Identify the transportation modes to be considered in this study.
- Conduct a practice review to identify how bicycle, pedestrian, scooter, and other user factors are currently being considered in transportation agencies.
- Evaluate methods of address these considerations within a pavement management system.
- Suggest feasible strategies for addressing these alternate modes of travel in a pavement management analysis.
- Validate the suggestions at one or more transportation agencies.
- Document the findings and suggestions in a report.
- Conduct activities to further the implementation of the suggestions.

Desired Products

- Suggestions on considering alternate modes of travel in a pavement management analysis.
- Implementation activities for putting the results into practice.

Estimated Timeframe and Cost

Cost: \$350,000

Duration: 24 months

6E: Develop and Pilot a Framework for Integrating Construction Costs and LCAs Into Pavement Management

Category of Work (Research, Training, Deployment, etc.): Research

Short- or Long-Term? Long-term

Description/Items to Be Addressed

Develop & pilot a framework for integrating construction costs & life cycle assessments (LCAs) into pavement management.

Primary Objectives

1. Develop a framework for incorporating construction materials and costs (including LCAs) into pavement management.
2. Develop commercial or open-source geo-spatial tools to generate information on pavement construction activities that impact pavement performance.

Proposed Research Activities (work steps)

Occasionally, there is a disconnect between what happens during pavement construction and the resulting pavement performance. In general, very little construction information is captured and documented in pavement management systems. Construction costs, including life cycle assessments, can also influence the selection or prioritization of pavement management projects and treatments. To better consider these factors within pavement management systems this study will help establish a better link between site-specific construction information and pavement performance issues. The research objectives will be accomplished through the following activities:

- Conduct a literature search to identify current practices for using construction data and LCAs in project and treatment selection.
- Identify available software tools that can help track pavement construction information using automated or semi-automated processes.
- Document key gaps and develop a framework for incorporating construction data and LCAs to address the gaps.
- Develop a geo-spatial tool that can be used to document information on pavement construction activities and how that information can be converted into inputs for the work history data in a PMS.
- Develop suggestions for using the construction and LCA data in a pavement management analysis.
- Pilot the suggestions and geo-spatial tool before finalizing the products.

Desired Products

- Suggestions on tracking and using construction data in a PMS.
- Software tool that agencies can use to track pavement construction information in the field and generate inputs for a PMS.
- User's guide for the tool's use.
- Implementation plan.

Estimated Timeframe and Cost

Cost: \$400,000

Duration: 24 months

7A: Identify Strategies For Using Federal Pavement Performance Measures

Category of Work (Research, Training, Deployment, etc.): Research

Short- or Long-Term? Short-term

Description/Items to Be Addressed

Identify strategies for addressing the reporting, target setting, & analysis implications of the 0.1-mile Federal requirements. (23 CFR 490.309)

Primary Objectives

1. Identify strategies that will overcome challenges with national performance measures.
2. Propose modifications to existing approaches based on the findings.
3. Document the suggestions and findings.

Proposed Research Activities (work steps)

National pavement performance measures were established as part of recent legislation. Since they have been established, there have been challenges identified with their use in urban areas, in terms of reporting conditions that vary from the conditions reported using legacy performance measures, and in setting future performance targets for 0.1-mile segments. Research will explore these issues and develop suggestions that support their implementation.

- Synthesize current practices in the use of Federal pavement performance measures.
- Identify challenges to be addressed, including their applicability in urban environments and discrepancies with legacy condition ratings.
- Investigate alternate strategies for addressing the gaps, including potential impacts.
- Suggest modifications to existing approaches based on the findings.
- Document findings and suggestions in a report.
- Present the findings to the FHWA.

Desired Products

- A final report documenting the findings and suggestions.
- Presentation of the findings to the FHWA.

Estimated Timeframe and Cost

Cost: \$150,000

Duration: 15 months

7B: Develop Processes for the Use of Performance Measures in Urban Areas

Category of Work (Research, Training, Deployment, etc.): Research

Short- or Long-Term? Long-term

Description/Items to Be Addressed

Summarize the use of performance measures to support pavement management in urban areas & develop suggestions for using pavement performance measures effectively in an urban environment.

Primary Objectives

1. Identify promising performance measures to be used in a pavement management system for urban environments.
2. Develop suggestions for their use.
3. Pilot the suggestions.

Proposed Research Activities (work steps)

Pavement projects in an urban environment impact many agencies' strategic objectives, including safety, mobility, and social equity objectives. However, traditional pavement management systems primarily consider current and future pavement conditions in making treatment suggestions based on cost-effectiveness. Pavement management practices in urban environments will benefit from the ability to consider non-traditional performance measures in project and treatment selection. This will be accomplished through the following:

- Conduct a literature review to identify current and desired performance measures (other than pavement condition) in urban environments.
- Assess the applicability and gaps in the measures identified.
- Identify the most promising measures that can be incorporated into a pavement management analysis.
- Develop suggestions on how these measures can be used.
- Pilot the suggestions in one or more urban environments and document the findings.
- Produce the final suggestions and implementation plan.

Desired Products

- List of promising urban performance measures.
- Suggestions for their use.
- Documentation of the benefits to using these measures.
- Implementation plan.

Estimated Timeframe and Cost

Cost: \$250,000

Duration: 24 years

9A: Identify Strategies to Enhance Local Access to Training

Category of Work (Research, Training, Deployment, etc.): Research

Short- or Long-Term? Short-term

Description/Items to Be Addressed

Identify strategies for addressing the demand for pavement management training among local agencies through the Local Technical Assistance Program (LTAP) and other sources.

Primary Objectives

1. Expand the availability and access to pavement management training for local agencies.

Proposed Research Activities (work steps)

LTAP centers are a primary source of training for local agency practitioners. LTAP centers are in each State and the types of training provided varies based on the unique resources available at each location. In the past, local agency pavement management training has developed to be taught through the LTAP centers and LTAP personnel were trained in how to teach the course. However, the material was primarily used by only a few LTAP centers where staff had prior training in pavement management. Local agencies would benefit from wider access to low-cost pavement management training materials to address workforce development demands. This research explores methods of providing pavement management training to local agencies and offers practical suggestions for putting the most promising approaches into practice. This will be accomplished through the following activities:

- Summarize available pavement management training current available for local agencies.
- Explore feasible methods to increase the availability of affordable training in local agencies, including changes to LTAP resources, online training programs, and other options.
- Obtain feedback from local practitioners on the viability of the most promising options.
- Develop suggestions for expanding the availability of pavement management training for local agencies.
- Document the findings and suggestions.

Desired Products

Suggestions for expanding local agency access to pavement management training courses.

Estimated Timeframe and Cost

Cost: \$125,000

Duration: 12 months

9B: Develop An Online, Searchable Pavement Management Guide

Category of Work (Research, Training, Deployment, etc.): Research

Short- or Long-Term? Short-term

Description/Items to Be Addressed

Develop an updated Pavement Management Guide to address current topics and deploy it as an online, searchable, updatable document.

Primary Objectives

1. Update the Pavement Management Guide to reflect changes in practice.
2. Incorporate more step-by-step instructions into the materials to address workforce development demands.
3. Provide an online, searchable version of the Guide.
4. Promote the use of the updated Guide among practitioners.

Proposed Research Activities (work steps)

The 2nd edition of the Pavement Management Guide was published in 2012. Since its publication there have been many changes in pavement management practices to be documented. The 2021 update to the *Pavement Management Roadmap* identified significant interest in developing more step-by-step assistance on many topics to support the practitioners' training demands. This research will address these demands through an update to the Pavement Management Guide in an online, searchable document that can be revised as new research and technical materials become available. The research objectives will be accomplished through the following activities:

- Identify new content to be addressed in the updated Pavement Management Guide.
- Present an approach for modifying or replacing the 2012 Pavement Management Guide, including suggestions for whether a print version will be published.
- Develop the material for the new Guide using available resources and case examples.
- Identify other resources that could be incorporated into an online version of the document, such as videos, training materials, and so on.
- Develop an online version of the updated Pavement Management Guide with search features and hyperlinks to the Pavement Management Roadmap.
- Conduct a book club to promote the completed Guide.

Desired Products

- An updated, online version of the Pavement Management Guide.
- A book club to promote the Guide's use by practitioners.
- Hyperlinks between the Pavement Management Guide and key topics from the Pavement Management Roadmap.

Estimated Timeframe and Cost

Cost: \$500,000

Duration: 30 months

9C: Develop Templates For Documenting Pavement Management Practices

Category of Work (Research, Training, Deployment, etc.): Research

Short- or Long-Term? Short-term

Description/Items to Be Addressed

Develop and make available templates for documenting pavement management models, treatment rules, processes, & procedures.

Primary Objectives

1. Develop templates to enable transportation agencies to document operating procedures and pavement management configuration details.
2. Pilot the use of the templates in one or more State DOTs.
3. Provide technical assistance to up to 5 States to implement the templates.

Proposed Research Activities (work steps)

Pavement management offices typically operate with a small staff, each with a specific set of job responsibilities. When one or more staff members retire, are promoted, or leave for other reasons, it can set the pavement management program back while the remaining staff learn new duties. The availability of a nonregulatory Pavement Management Handbook that documents standard operating procedures would greatly benefit agencies facing these types of staff changes. This research creates templates to simplify the task of documenting pavement management practices and supports the implementation of the templates in up to 5 State DOTs. The research objectives are achieved through the following activities:

- Summarize the suggested content for a nonregulatory Pavement Management Handbook documenting pavement management standard operating procedure.
- Identify sections that would benefit from templates.
- Create electronic templates that simplify the process of filling in the Handbook.
- Test the templates in a State DOT.
- Finalize the templates and make them available for public use.
- Provide technical assistance to up to 5 State DOTs to advance their documentation efforts.

Desired Products

- Electronic templates for documenting pavement management practices.
- Sample materials.
- Completed documentation from 5 State DOTs.

Estimated Timeframe and Cost

Cost: \$400,000

Duration: 24 months

14A: Develop Automated Approaches for Processing and Analyzing Pavement Management Data

Category of Work (Research, Training, Deployment, etc.): Research

Short- or Long-Term? Long-term

Description/Items to Be Addressed

Develop automated approaches for processing and analyzing pavement management data.

Primary Objectives

1. Identify improvements that could be made to existing data processing and analysis techniques used in pavement management using new and emerging techniques such as machine learning and artificial intelligence.
2. Identify areas within pavement management (e.g., performance models, decision tree development, workplan optimization, etc.) where the techniques can be applied.
3. Identify modifications to existing pavement management system software to support the techniques identified.

Proposed Research Activities (work steps)

Data collection technologies and methodologies change regularly, and this creates several challenges for agencies trying to use the data to model pavement performance—such as shorter duration of pavement performance history data collected using a particular technology, inconsistencies in referencing systems used over time, etc. Agencies would benefit from new and emerging approaches that can not only be used to address these challenges but can also be leveraged to advance the current state of practice in pavement management. The research will involve the following activities:

- Conduct a literature review to identify new and emerging tools and techniques that can help improve pavement management analysis.
- Develop suggestions on how to use these techniques effectively using simple illustrative examples.
- Develop simple software tools to help agencies implement identified techniques.
- Develop suggestions for how to incorporate these techniques into pavement management systems.

Desired Products

- Suggestions on how to use the research results effectively for a pavement management analysis.
- Simple software tools to help promote the use of the new techniques.
- Implementation plan.

Estimated Timeframe and Cost

Cost: \$350,000

Duration: 18 months

14B: Develop Technology to Assess Drainage Conditions

Category of Work (Research, Training, Deployment, etc.): Research

Short- or Long-Term? Long-term

Description/Items to Be Addressed

Develop technology to assess drainage conditions with minimal manual involvement.

Primary Objectives

1. Identify drainage data elements to support pavement management decisions.
2. Evaluate methods of collecting the necessary information, focusing on limiting manual involvement as much as possible.
3. Test the viability of the most promising approach for collecting drainage information.
4. Develop a prototype for collecting the data.
5. Document the results.

Proposed Research Activities (work steps)

Since drainage features are not always visible from the road when traveling at traffic speeds, surveys conducted using automated equipment do not collect drainage inventory or condition information. However, drainage conditions can have a significant role in pavement performance. Agencies would benefit from an automated process for collecting drainage inventory and condition information to support pavement management decisions. This research will produce a prototype demonstrating the feasibility of collecting drainage information on a network-wide basis through the completion of the following activities:

- Phase 1:
 - Survey practitioners to better understand the desired drainage features to collect.
 - Identify potential approaches for collecting this information, including benefits and limitations to each approach.
 - Identify the most promising approach for collecting drainage information.
 - Prepare suggestions for the approach to be used.
- Phase 2:
 - Develop a prototype demonstrating the feasibility of collecting drainage information using automated means.
 - Validate data from the prototype with manual methods.
 - Develop criteria for further development of the equipment.
 - Document the results.

Desired Products

- A practical approach for collecting drainage information to support pavement management.
- Prototype.
- Proposed steps for further development.
- Documentation of the validation results.

Estimated Timeframe and Cost

Cost: \$600,000

Duration: 36 months

14D: Develop Equipment to Evaluate Structural Condition on Low-Level Roads and on Rigid Pavements

Category of Work (Research, Training, Deployment, etc.): Research

Short- or Long-Term? Long-term

Description/Items to Be Addressed

Develop equipment to assess pavement structural condition to address data collection on low-level roads where semis are not a viable option and better applicability to rigid pavements.

Primary Objectives

1. Identify potential modifications and/or enhancements to TSDDs to accurately characterize the structural condition of rigid pavements.
2. Identify potential modifications to TSDDs that use a data collection method that does not use a semi-trailer.
3. Develop and produce the new equipment.

Proposed Research Activities (work steps)

Traffic speed deflection devices today have at least two characteristics that hinder their widespread use. First, the devices are generally perceived to be less applicable for characterizing the structural capacity of rigid pavements. Additionally, the use of a semi-trailer to collect data on some low-volume roads is not desirable. It would enhance the testing capabilities of TSDDs to make them more applicable under these circumstances. To accomplish the research objectives, the following activities will be conducted:

- Phase 1:
 - Query TSDD users and practitioners to better understand the issues related with the use of TSDDs on rigid pavements and identify functionality better suited to rigid pavements.
 - Query TSDD users and potential users to better understand the issues related with the use of TSDDs on low-volume roads and identify potential modifications that would overcome this challenge.
 - Prepare suggestions for changes to equipment to address one or both of these issues.
- Phase 2:
 - Develop next-generation TSDD equipment that can accurately characterize the structural condition of both flexible and rigid pavements using a smaller piece of equipment.
 - Validate data from the next-generation TSDD equipment using traditional deflection testing devices.
 - Develop nonregulatory criteria and suggestions for the use of the next-generation TSDDs.

Desired Products

- Report documenting modifications and/or enhancements to TSDDs to make them better suited to characterizing the structural condition of rigid pavements and more feasible on low-volume roads.
- Development of next-generation TSDD equipment that is available for use.

Estimated Timeframe and Cost

Cost: \$1,000,000

Duration: 48 months

14E: Develop Equipment for Continuous Friction Measurements

Category of Work (Research, Training, Deployment, etc.): Research

Short- or Long-Term? Long-term

Description/Items to Be Addressed

Develop equipment for continuous friction measurements.

Primary Objectives

1. Develop non-contact sensor-based approaches to measure pavement friction at highway speeds.
2. Demonstrate the feasibility and cost-effectiveness of the most promising approach.

Proposed Research Activities (work steps)

There is an opportunity to enhance highway safety through better monitoring of pavement surface characteristics related to friction (such as microtexture, macrotexture, and megatexture). Existing procedures to collect friction data have some inherent limitations (equipment operation safety, testing speed, operating temperature, etc.) that impact testing scalability to the network-level. The research objectives will be accomplished through the completion of the following activities:

- Conduct a literature search of recent research related to traffic-speed assessment of pavement friction using non-contact sensors.
- Identify benefits and limitations to existing testing equipment and procedures.
- Determine the most effective and accurate methodology to measure pavement friction at highway speeds.
- Suggest methodologies to address equipment and/or analysis limitations.
- Refine equipment and/or analysis procedures.
- Demonstrate the equipment capabilities and analysis techniques.

Desired Products

- Data collection equipment that operates at highway speeds and provides accurate measurement of pavement friction using non-contact sensors.
- Deployment materials on using the results in a pavement management analysis.

Estimated Timeframe and Cost

Cost: \$800,000

Duration: 48 months

14F: Develop Strategies to Improve the Implementation of University Research

Category of Work (Research, Training, Deployment, etc.): Research

Short- or Long-Term? Long-term

Description/Items to Be Addressed

Develop strategies to facilitate the implementation of university research to advance pavement management.

Primary Objectives

1. Improve the applicability of university research to pavement management practitioners.
2. Reduce the amount of time needed to adopt promising practices.
3. Establish a framework for on-going collaboration between pavement management practitioners and academia.

Proposed Research Activities (work steps)

University studies show promise for advancing pavement management practices, but research results are not widely known among practitioners and/or ways to implement the results are not obvious. This research strives to overcome these hurdles by improving the applicability of university research to practitioners' demands and simplifying the implementation process. It also provides a framework for an on-going dialog between practitioners and academics to ensure research efforts are aligned. These objectives will be accomplished through the following activities:

- Form an advisory group of academics and practitioners with experience in pavement management.
- Identify strategies for establishing closer collaboration between the two groups.
- Document the benefits and challenges associated with the possible approaches.
- Select the most viable approach.
- Document the findings and suggestions.

Desired Products

Methodology and implementation approach to strengthen the implementation of university research to advance pavement management practices.

Estimated Timeframe and Cost

Cost: \$175,000

Duration: 18 months

1G: Develop Deployment Materials on Data Collection Activities

Category of Work (Research, Training, Deployment, etc.): Deployment

Short- or Long-Term? Short-term

Description/Items to Be Addressed

Develop deployment strategies for:

- Contracting data collection activities.
- Use of TSDD data to define network structural condition.
- Quantifying the value of using network-level structural data in a PMS.
- Using GPR.
- Using macrotexture.
- Using existing equipment to collect asset inventory & condition information for curb ramps, signage, sidewalks, curb & gutter, and other information.
- Integrating utility information into a PMS.
- Streamlining data collection activities.

Primary Objectives

1. Develop materials on managing changes in data due to equipment or raters, including the development of tools to aid in maintaining consistency.
2. Develop materials on the use of LiDAR for collecting data on ancillary assets, including processes for determining asset inventories and conditions for curb ramps, signage, sidewalks, curb and gutter, and other important information.
3. Evaluate the cost-effectiveness of piggybacking pavement management data collection activities to include atypical data such as friction testing, structural deflection, ROW imaging, and asset takeoff in addition to standard distress data.

Proposed Research Activities (work steps)

The project objectives will be achieved through the following activities:

- Conduct a literature review of current data collection strategies and challenges.
- Develop suggestions to address the topics listed.
- Develop tools to aid in maintaining consistency following changes in data collection equipment or raters.
- Pilot the suggestions and tools.
- Evaluate the cost-benefit of implementing the suggestions.
- Finalize the products and prepare implementation materials.

Desired Products

- Materials to improve pavement management data collection activities, including a cost-effectiveness analysis.
- Tools to aid in managing data consistency.

Estimated Timeframe and Cost

Cost: \$600,000

Duration: 48 months

2G: Develop Deployment Strategies to Support Data Quality

Category of Work (Research, Training, Deployment, etc.): Deployment

Short- or Long-Term? Short-term

Description/Items to Be Addressed

Develop deployment strategies for:

- Addressing challenges with transitions in procedures & addressing differences temporally & spatially.
- Improving consistency between raters and/or years.
- Implementing automated data quality checks & processes for interim data acceptance.
- Using the nonregulatory acceptance criteria established through the FHWA Pooled Fund TPF-5(299) & (399).
- Using data sampling.
- Certifying equipment and operators.

Primary Objective

1. Develop deployment strategies that support the development and use of Data Quality Management Programs (DQMPs), providing the background necessary for practitioners to understand the importance of each component, the factors that most influence data quality, steps that can be taken to improve data quality, and how transitions in equipment should be managed.

Proposed Research Activities (work steps)

Transportation agencies currently use DQMPs to establish the framework for evaluating data quality, but the content is not well understood, and practitioners do not feel confident in addressing issues that affect data quality. This study provides the background that allows practitioners to have confidence in developing and using their DQMPs. The project objectives will be accomplished through the following activities:

- Identify the key issues to be addressed.
- Develop strategies to address these issues.
- Promote the strategies among practitioners.

Desired Products

- Strategies and deployment materials.
- Webinar or other method of sharing the results with practitioners.

Estimated Timeframe and Cost

Cost: \$175,000

Duration: 18 months

2H: Develop and Pilot a Framework for Addressing the Road Data Deficiencies on Tribal Lands

Category of Work (Research, Training, Deployment, etc.): Deployment

Short- or Long-Term? Short-term

Description/Items to Be Addressed

The Government Accountability Office (GAO) conducted a study titled “Tribal Transportation: Better Data Could Improve Road Management and Inform Indian Student Attendance Strategies” (GAO-17-423). The GAO study findings indicate inaccuracies in road condition and maintenance data reported on tribal land roads eligible for Federal funding. Additionally, the study indicates incomplete and inconsistent road descriptions and condition information along with under reporting maintenance activities, which raised questions about the continued value of collecting roadway descriptions and condition data. The opportunities outlined in the May 22, 2017 GAO report indicate the National Tribal Transportation Facility Inventory (NTTFI) reflects a current list of federally eligible tribal routes that are managed using data fields within the Road Inventory Field Data System (RIFDS) as the databases to reconcile.

Primary Objectives

1. Identify inequities in policies and programs that serve as barriers to equal opportunity.
2. Address the lack of availability in roadway data information that accurately reflects the infrastructure needs in Indian Country.
3. Integrate the NTTFI with existing GIS-based FHWA data systems.
4. Improve road data collection, quality, accuracy, and accessibility for the NTTFI so that it better informs the TTP.
5. Address recommendation 1 from GAO-17-423.

Proposed Research Activities (work steps)

- Evaluate current processes and establish an electronic framework for a GIS-capable NTTFI that is compatible with the FHWA data management systems (FY22).
- Establish data quality metrics (FY22).
- Migrate existing FHWA data to the new NTTFI (FY23).
- Migrate BIA data to new NTTFI while applying the FHWA data quality metrics (FY23).
- Identify other documents needed for data-driven decision making (FY24).

Desired Products

- An electronic framework for a GIS-capable NTTFI that is compatible with the FHWA data management systems and populated with existing FHWA and BIA data.
- Data quality metrics.
- Other documents needed for data-driven decision making.

Estimated Timeframe and Cost

Cost: \$750,000

Duration: 48 months

3E: Develop Deployment Strategies For Managing Data

Category of Work (Research, Training, Deployment, etc.): Deployment

Short- or Long-Term? Short-term

Description/Items to Be Addressed

Develop deployment strategies for:

- Integrating various data sources, including LRS issues.
- Storing large amounts of data.
- Documenting data with proper metadata.

Primary Objective

1. Develop deployment strategies to improve the management of pavement management data.

Proposed Research Activities (work steps)

In advance of long-term research to explore the use of innovative technology to support data management, information is desired to help agencies address common issues for managing pavement management data, such as storing large amounts of data, establishing data governance criteria, and merging data from various sources. The project objective will be accomplished through the following activities:

- Identify the key issues to be addressed.
- Develop strategies to address these issues.
- Promote the strategies among practitioners.

Desired Products

- Strategies and deployment materials.
- Webinar or other method of sharing the results with practitioners.

Estimated Timeframe and Cost

Cost: \$175,000

Duration: 18 months

4E: Develop Deployment Strategies to Enhance Pavement Performance Modeling

Category of Work (Research, Training, Deployment, etc.): Deployment

Short- or Long-Term? Short-term

Description/Items to Be Addressed

Develop strategies for:

- Developing performance models, including techniques for modeling with no historic data.
- Evaluating model reasonableness & reliability.
- Determining when models should be updated.
- Using TSDD data in performance models.
- Incorporating risks into models, including current and future environmental risks.
- Evaluating the impact of risk on project conditions.
- Using models to calibrate pavement design procedures.
- Using data science to evaluate trends & treatment effectiveness.
- Documenting models.

Primary Objectives

1. Develop detailed suggestions for developing and updating pavement performance models that provides strategies for addressing missing data, determining the reasonableness of the models, and evaluating whether updates would be beneficial.
2. Expand the suggestions to include strategies for including new factors in the models, including TSDD data, risk, and other factors.
3. Explain how the models can be used to calibrate pavement design procedures.
4. Illustrate how data science techniques can be used to evaluate trends and determine treatment effectiveness.
5. Develop a template for documenting models.

Proposed Research Activities (work steps)

Pavement performance modeling is integral to an effective pavement management system. Information is desired on how to develop effective pavement performance models, including “how-to-steps” for model development, accounting for “noisy” data, changes in design, traffic, materials, and so on.

The project work will recognize and make use of any prior work that has been completed. For instance, at least 27 States are participating in the TSDD pooled fund, TPF-5(385) and many are using the data for both network and project assessments. Eastern Federal Lands has also collected TSDD on over 2,000 mile of Parkway routes managed by the National Park Service and will use some of this data for a design-build effort. Eastern Federal Lands is also planning a GPR initiative that could be beneficial to the development of deployment materials.

The project objective will be met through the completion of the following activities:

- Conduct a literature review to determine current practices in pavement performance modeling.
- Develop case studies showcasing well-developed performance modeling practices in the areas identified.
- Establish strategies for developing and updating pavement performance models that address the factors outlined in the project objective.
- Prepare an implementation plan to promote the results.

Desired Products

- Strategies for developing and updating effective performance models.
- Implementation plan.

Estimated Timeframe and Cost

Cost: \$350,000

Duration: 30 months

5B: Develop Strategies To Improve Project and Treatment Selection

Category of Work (Research, Training, Deployment, etc.): Deployment

Short- or Long-Term? Short-term

Description/Items to Be Addressed

Develop deployment strategies for:

- Incorporating maintenance & preventive maintenance treatments into a PMS.
- Incorporating TSDD results into decision trees.
- Determining conditions under which treatments are viable (e.g., proactive maintenance, low or high preservation, minor or major rehabilitation).
- Considering variations in existing conditions when defining the impact of preventive maintenance treatments.
- Documenting treatment rules.

Primary Objective

1. Develop strategies to support project and treatment selection through improved decision trees that better consider maintenance, structural data, and preventive maintenance treatments.

Proposed Research Activities (work steps)

Pavement management decision trees have a significant influence on the projects and treatments that are suggested. Practitioners may be hesitant to modify decision trees because they do not understand all of the implications to the changes. This has resulted in delays in establishing decision trees for preventive maintenance treatments or in adding structural and maintenance factors. The strategies developed under this effort provide specific suggestions for addressing these issues. The project objective will be accomplished through the following activities:

- Identify the key issues to be addressed.
- Develop strategies to address these issues.
- Promote the strategies among practitioners.

Desired Products

- Strategies and deployment materials.
- Webinar or other method of sharing the results with practitioners.

Estimated Timeframe and Cost

Cost: \$175,000

Duration: 18 months

6B: Develop Strategies on Improving the Match Between Pavement Management Project Suggestions and Funded Projects

Category of Work (Research, Training, Deployment, etc.): Deployment

Short- or Long-Term? Short-term

Description/Items to Be Addressed

Develop strategies for aligning pavement management suggestions with programmed projects.

Primary Objective

1. Develop strategies to improve the match between pavement management suggestions and funded projects in both centralized and decentralized organizations.

Proposed Research Activities (work steps)

Consistency determinations conducted annually by the FHWA Division Offices seek to determine whether a State DOT “has developed and implemented an asset management plan consistent with 23 U.S.C 119.” (23 CFR 515.13(b)). One way to show consistency is to demonstrate alignment between the actual and planned levels of investment for various work types (i.e., initial construction, maintenance, preservation, rehabilitation, and reconstruction). These investments are not always aligned due to various factors. One step toward improving the alignment is to establish a stronger match between the suggestions from a pavement management system and the construction program. State DOTs have indicated interest in improving this alignment. This study investigates the approaches that have been used and provides suggestions for putting these approaches into practice. The project objective will be accomplished through the following activities:

- Identify agencies that have implemented processes to improve the alignment between pavement management suggestions and funded projects.
- Document the most promising practices into case studies.
- Develop strategies for improving the match.
- Promote the strategies among practitioners.

Desired Products

- Strategies and deployment materials.
- Webinar or other method of sharing the strategies with practitioners.

Estimated Timeframe and Cost

Cost: \$175,000

Duration: 18 months

6G: Develop Strategies for Maximizing the Use of Pavement Management Analysis Results

Category of Work (Research, Training, Deployment, etc.): Deployment

Short- or Long-Term? Short-term

Description/Items to Be Addressed

Develop strategies for:

- Establishing an effective feedback loop.
- Determining whether new software tools would be beneficial.
- Using PMS results in a multi-objective project selection process.
- Incorporating risk & resilience into an analysis.
- Selecting projects that improve agency resilience.
- Evaluating the impact that new developments have on conditions when assessing future funding levels.
- Defining “backlog.”

Primary Objectives

1. Develop strategies to maximize the use of existing pavement management information within an agency.

Proposed Research Activities (work steps)

Pavement management systems have primarily been used to address traditional applications, such as estimating funding demands, predicting the impact of different investment levels on network conditions, and identifying the best use of available funding. Pavement management systems have the potential to be used for so much more with little to no changes to the existing configuration. This study addresses potential applications for existing pavement management data that can benefit the agency. The project objectives will be accomplished through the following activities:

- Identify the key issues to be addressed, including those listed above.
- Develop strategies to address these issues.
- Promote the strategies among practitioners.

Desired Products

- Strategies and deployment materials.
- Webinar or other method of sharing the strategies with practitioners.

Estimated Timeframe and Cost

Cost: \$175,000

Duration: 18 months

7D: Develop Strategies for Data-Driven Target Setting

Category of Work (Research, Training, Deployment, etc.): Deployment

Short- or Long-Term? Short-term

Description/Items to Be Addressed

Develop strategies for data-driven target setting.

Primary Objective

1. Develop strategies for how to use pavement management data to establish pavement performance targets.

Proposed Research Activities (work steps)

NCHRP 23-07, Effective Methods for Setting Transportation Performance Measures, will provide different approaches that can be used for effective target setting. This study applies the lessons learned from that research to pavement management target setting using examples from State DOTs. The project objectives will be accomplished through the following activities:

- Identify the approaches that lend themselves to pavement management target setting.
- Demonstrate the use of the approaches using pavement management data.
- Develop strategies that practitioners can use to improve their target-setting practices.
- Promote the strategies among practitioners.

Desired Products

- Strategies and deployment materials.
- Webinar or other method of sharing the strategies with practitioners.

Estimated Timeframe and Cost

Cost: \$175,000

Duration: 18 months

12A: Develop Strategies for Presenting Pavement Management Results

Category of Work (Research, Training, Deployment, etc.): Deployment

Short- or Long-Term? Short-term

Description/Items to Be Addressed

Develop strategies for presenting pavement management results and communicating the long-term impact of deferred investment.

Primary Objective

1. Develop strategies on communicating pavement management results effectively so the long-term impacts of decisions are understood.

Proposed Research Activities (work steps)

The results from a pavement management analysis provide important information for making investment decisions, including the potential long-term consequences of deferred investment. However, the information presented can be too technical for some stakeholders. Therefore, strategies are desired to help transportation agencies communicate impacts more effectively using innovative graphics and data analytics. This study provides strategies for communicating pavement management results effectively. The project objective will be accomplished through the following activities:

- Define the key messages to be addressed.
- Identify strategies to address these issues and produce examples.
- Develop materials that summarize the results.
- Promote the findings among practitioners.

Desired Products

- Strategies and deployment materials.
- Webinar or other method of sharing the results with practitioners.

Estimated Timeframe and Cost

Cost: \$175,000

Duration: 18 months

13B: Develop Strategies for Overcoming Organizational Silos Impacting Pavement Management

Category of Work (Research, Training, Deployment, etc.): Deployment

Short- or Long-Term? Short-term

Description/Items to Be Addressed

Develop strategies for overcoming organizational silos impacting pavement management, recognizing the benefits to cross training, multi-discipline collaboration, and succession planning.

Primary Objectives

1. Identify how organizational structures can impact pavement management practices.
2. Explore strategies for addressing organizational silos, including cross training, multi-discipline collaboration, and succession planning.
3. Select strategies to overcome those hurdles.
4. Develop ways to put the findings into practice.

Proposed Research Activities (work steps)

In advance of long-term research to explore the use of innovative technology to support data management, strategies are desired to help agencies address common issues for managing pavement management data, such as storing large amounts of data, establishing data governance criteria, and merging data from various sources. The project objectives will be accomplished through the following activities:

- Summarize traditional means of addressing issues related to agency organization that impact pavement management.
- Identify characteristics associated with the traditional approaches, including what works and when it works.
- Explore other strategies for overcoming organizational silos, including cross training, multi-discipline collaboration, and succession planning. These strategies may address issues related to recruiting, retaining, rewarding, training, promoting, and removing employees.
- Test the promising strategies with a select group of practitioners.
- Prepare suggestions on how to apply the most promising strategies in a transportation agency.
- Promote the results among practitioners.

Desired Products

- Strategies and deployment materials.
- Webinar or other method of sharing the strategies with practitioners.

Estimated Timeframe and Cost

Cost: \$250,000

Duration: 24 months

14C: Establish Strategies for Using New Technology to Support Pavement Management

Category of Work (Research, Training, Deployment, etc.): Deployment

Short- or Long-Term? Short-term

Description/Items to Be Addressed

Establish strategies for:

- Using data from crowdsourced data, CAVs, UAS, and other automated technology to support pavement management analysis.
- Documenting precision/bias statements that can be put into practice.
- Using new technology in concert with traditional data collection practices.
- Replacing outdated technology with proven new technology.
- Applying the Technology Readiness Level Guidebook published by NASA to evaluate whether new technology is ready to be implemented.

Primary Objectives

1. Develop a framework to evaluate new and emerging data collection technologies to support pavement management activities.
2. Establish nonregulatory criteria and practices to ensure consistent use of the new technology.
3. Identify technical support strategies to implement the results.

Proposed Research Activities (work steps)

New tools and technologies related to managing pavements are often marketed to highway agencies. Unlike the evaluation of a new pavement material or design method, determining the utility of such pavement management tools and technologies is not always straightforward. Agencies will benefit from suggestions for appropriate methodologies to evaluate new technologies and determine the potential benefits associated with each technology. The project objectives will be accomplished through the following activities:

- Develop a framework to evaluate new technology for pavement management that addresses the following types of questions:
 - What is the evaluation process?
 - Why should agencies adopt this new technology?
 - How does this technology compare to existing methodologies?
 - Does this new technology adhere to existing criteria and procedures, or should new ones be developed?
- Develop generic criteria that will help establish consistent use of each new technology identified and for assessing future technologies.
- Pilot the strategies and document findings.

Desired Products

- A framework for evaluating new and emerging data collection technologies for pavement management.
- Implementation plan.

Estimated Timeframe and Cost

Cost: \$150,000

Duration: 12 months

15A: Develop and Pilot Strategies for Using Leading Performance Measures

Category of Work (Research, Training, Deployment, etc.): Deployment

Short- or Long-Term? Short-term

Description/Items to Be Addressed

Develop and pilot strategies for using leading measures, such as structural data, to influence pavement management decisions.

Primary Objectives

1. Identification of leading performance measures to support pavement management.
2. Suggestions for using leading performance measures in a pavement management analysis.
3. Documentation of the key differences in using leading rather than lagging measures.
4. Suggestions for implementing the results.

Proposed Research Activities (work steps)

Projects identified using a pavement management system impact highway conditions and performance. Traditional pavement management analyses use lagging performance measures that estimate the conditions after a particular action has been taken. Current FHWA research is exploring the benefits to using leading performance measures to drive investment decisions to better ensure that targeted performance expectations will be met. This study will develop strategies for the use of leading performance measures through the conduct of the following tasks:

- Identify and describe leading performance measures that show promise for improving pavement management analyses.
- Develop strategies for the use of leading performance measures in a pavement management system.
- Validate the strategies through a pilot study in one or more State DOTs.
- Document differences in the decisions using leading and lagging measures.
- Finalize the strategies and provide suggestions for implementation.

Desired Products

- Strategies for using leading performance measures.
- Documentation showing the benefits to the use of leading performance measures.
- Implementation plan.

Estimated Timeframe and Cost

Cost: \$200,000

Duration: 24 months

15B: Develop and Pilot Strategies for the Use of Non-Traditional Performance Measures

Category of Work (Research, Training, Deployment, etc.): Deployment

Short- or Long-Term? Long-term

Description/Items to Be Addressed

Develop and pilot strategies for the use of non-traditional performance measures (e.g., crash reduction, complete streets components, ADA facilities, other travel models, and social equity) to support project and treatment selection processes.

Primary Objectives

1. Develop strategies for using non-traditional performance measures to support pavement management decisions.
2. Pilot the strategies.
3. Promote the use of the strategies.

Proposed Research Activities (work steps)

Research has explored the potential use of non-traditional performance measures such as social equity, crash reduction, and so on to support the selection of projects and treatments. Since the results of the research will not be available for years, interim strategies are desired to demonstrate the feasibility of using non-traditional performance measures. The project objectives will be accomplished through the following activities:

- Identify the non-traditional performance measures to be addressed.
- Identify and document case studies where these non-traditional performance measures have been used.
- Develop materials to describe how the non-traditional performance measures can be used.
- Pilot the strategies in at least one State and one local transportation agency.
- Promote the results among practitioners.

Desired Products

- Summary of current practice showing how non-traditional performance measures are being used.
- Strategies and deployment materials
- Pilot study
- Webinar or other method of sharing the results with practitioners.

Estimated Timeframe and Cost

Cost: \$250,000

Duration: 24 months

TECHNICAL ASSISTANCE ACTION ITEMS

10A: Pilot and Implement a Pavement Management Technical Assistance Program

Category of Work (Research, Training, Deployment, etc.): Technical Assistance

Short- or Long-Term? Short

Description/Items to Be Addressed

Pilot and implement a technical assistance program on:

- Data management, data quality, & other data-related issues.
- Pavement performance modeling and use of a feedback loop.
- Documenting pavement management practices.

Primary Objective

1. Advance pavement management practices by providing technical assistance to State DOTs seeking support in particular technical areas.

Proposed Research Activities (work steps)

Pavement management practices are not commonly taught at universities and limited training is available to support the development of desired skills. This effort develops and implements a Pavement Management Technical Assistance Program to support State DOTs with data management, pavement performance modeling, system documentation, or other technical areas. The program consists of up to 200 hours of technical support to agencies selected to participate in the program. For each agency selected:

- A kick-off meeting will be conducted to identify the desired assistance.
- A work plan will be developed to document roles, responsibilities, and timeline.
- The technical support will be provided.
- A short report will be prepared summarizing the effort.

The cost estimate assumes technical support will be provided to up to 5 agencies as a pilot, but the program can be extended to address the interests of other agencies.

Desired Products

- Up to 200 hours of technical assistance to 5 selected State DOTs.
- A summary report documenting the work completed in each agency.

Estimated Timeframe and Cost

Cost: \$400,000

Duration: 24 months

10B: Develop a National Equipment Certification Center

Category of Work (Research, Training, Deployment, etc.): Technical Assistance

Short- or Long-Term? Long-term

Description/Items to Be Addressed

Develop an independent National Equipment Certification Center that can be used by public and private agencies to certify equipment used to conduct network-level pavement condition surveys.

Primary Objectives

1. Summarize criteria for establishing an independent National Equipment Certification Center.
2. Develop and pilot the National Equipment Certification Center.
3. Open the National Equipment Certification Center for widespread use.

Proposed Research Activities (work steps)

Working in conjunction with TPF-5(299)/(399) the research will:

- Identify pavement distress calibration and certification criteria to be administered.
- Define calibration site criteria.
- Construct a pilot site to test the criteria with various equipment and operators.
- Expand the certification site based on the lessons learned.
- Develop a final report and implementation plan that addresses the long-term viability of the National Equipment Certification Center.

Desired Products

An independent National Equipment Certification Center that can be used by public and private agencies with equipment used to conduct network-level pavement condition surveys.

Estimated Timeframe and Cost

Cost: \$1,500,000

Duration: 48 months

10C: Conduct Pilot Programs to Demonstrate New Pavement Management Practices

Category of Work (Research, Training, Deployment, etc.): Technical Assistance

Short- or Long-Term? Long-term

Description/Items to Be Addressed

Conduct pilot programs to demonstrate:

- The use of new technology.
- Benefits to using the next generation performance measures.
- Return on investment from using GPR and TSDD data.
- Strategies for using PMS data to support multi-objective decision analysis.
- The conversion of research results into practice.
- Use of PMS data to support maintenance scheduling and planning.
- Successful transition strategies (such as recruiting, retention, training, and promotion).

Primary Objectives

1. Demonstrate the applicability of small, unmanned aircraft systems (UAS) for pavement management.
2. Demonstrate the benefits to using next-generation performance measures on pavement management decisions.
3. 3. Quantify the return on investment from the use of data collection technology not commonly considered in pavement management (such as GPR and TSDD).
4. Assist agencies with trial uses of multi-objective decision analysis to explore differences in analysis results.
5. Provide the assistance necessary to support the implementation of research efforts into practice.
6. Demonstrate the use of pavement management data to support maintenance scheduling and planning.
7. Demonstrate the implementation of workforce transition planning tools related to recruitment, retention, rewards, training, promotions, and removal.

Proposed Research Activities (work steps)

For new or innovative practices to be implemented, agencies want to better understand how the technology or practice can be used to support pavement management. Therefore, each pilot program will be conducted using the following steps:

- Identify the technology or practice that will be demonstrated.
- Conduct a literature review to identify well-established practices in this area.
- Document the practices that will be demonstrated.
- Identify agencies that would benefit from the demonstration project.
- Conduct the pilot projects to demonstrate the application of the practices or technology.
- Document the results.
- Prepare case study documents to promote the use of the practice or technology among other agencies.

Desired Products

- Implementation of practices or technology to advance their use in selected states.
- Pilot study report.
- Case studies to promote the practice or technology nationally.

Estimated Timeframe and Cost

Cost: \$200,000 apiece, \$1,400,000 for all 7

Duration: 18 months each

10D: Develop an Equipment Loan Program

Category of Work (Research, Training, Deployment, etc.): Technical Assistance

Short- or Long-Term? Short-term

Description/Items to Be Addressed

Develop an equipment loan program to enable agencies an opportunity to test new technology.

Primary Objectives

1. Increase the likelihood that promising technology will be adopted to support pavement management efforts.
2. Obtain feedback from agencies on the costs and benefits to the use of new technology that can be shared with others.

Proposed Research Activities (work steps)

Under this program, the FHWA will purchase equipment that can be loaned to State DOTs for a fixed amount of time to evaluate the benefits to adopting the technology. Depending on the type of equipment included in the program, training may be provided to the receiving agency at the start of the loan program. The advantage to the State DOTs is that they don't have to buy the equipment or technology before determining its applicability.

Desired Products

Equipment loan program to support pavement management.

Estimated Timeframe and Cost

Cost: \$600,000

Duration: 4 years

10E: Develop a Program for New Technology Trials

Category of Work (Research, Training, Deployment, etc.): Technical Assistance

Short- or Long-Term? Long-term

Description/Items to Be Addressed

Develop a program to support new technology trials.

Primary Objective

1. Advance the use of new technology among State DOTs by reducing the agency's risks.

Proposed Research Activities (work steps)

There are certain types of new technology that would be beneficial to pavement management programs, but do not fit into a traditional equipment loan program. For instance, if an agency wanted to evaluate the potential use of crowd-sourced data, the agency would have to commit to acquiring the data without knowing its potential. Under this program, select State DOTs would receive grants to cover the initial costs associated with acquiring the technology. By eliminating the risks associated with the upfront costs, agencies may be more likely to consider alternate methods of collecting or analyzing data.

Desired Products

- Opportunities to test new technology without upfront costs.
- Summary reports from each participating agency to capture benefits that other agencies may be interested in.

Estimated Timeframe and Cost

Cost: \$1,000,000 annually, total \$5,000,000 for 5 years

Duration: 60 months

1D, 1E, 3C, 6H: Synthesis Topics

Category of Work (Research, Training, Deployment, etc.): Synthesis
Short- or Long-Term? Short-term

Description/Items to Be Addressed

Synthesize practices on:

- Collection of inventory and condition data on lower-level roadways, shoulders, & ramps, and the benefits associated with collecting this information.
- Successful practices for contracting pavement management data collection.
- Agency policies on data storage, including any limitations imposed by oversight agencies.
- Effective data visualization and communication efforts to support project selection and scoping.

Primary Objective

1. Synthesize current pavement management practices.

Proposed Research Activities (work steps)

The typical synthesis projects consist of a survey of practice, a summary of practices, and case examples highlighting well-established practices in the area. Each synthesis is typically completed in 12 months.

Desired Products

Synthesis.

Estimated Timeframe and Cost

Cost: \$50,000 each, \$200,000 total for 4

Duration: 12 months each

PEER EXCHANGE ACTION ITEMS

1F, 2F, 3D, 4D, 6F, 7C: Peer Exchange Topics

Category of Work (Research, Training, Deployment, etc.): Peer Exchange

Short- or Long-Term? Short-term

Description/Items to Be Addressed

- Conduct a peer exchange to discuss strategies for addressing contracting issues associated with data collection activities and improving the timeliness of survey data.
- Conduct a peer exchange to discuss how agencies are a) addressing challenges in data collection equipment transitions, b) reconciling differences temporally & spatially, c) verifying cracking, transverse profile, & faulting values, d) developing stability in ratings when procedures change, e) preparing & following an effective DQMP, establishing data acceptance criteria.
- Conduct a peer exchange to address the use of BIM/CIM and e-construction data to populate pavement histories.
- Conduct a peer exchange to discuss techniques and practices associated with pavement performance modeling.
- Conduct a peer exchange to discuss a) how a PMS is used to support life cycle planning, b) typical matches between analysis results & projects, and c) use of PMS data to support other departments.
- Conduct a peer exchange to discuss a) how agencies are explaining & analyzing differences in State and Federal measures, b) ideas for improving Federal measures, and c) how to use pavement management data to set performance targets.

Primary Objectives

1. Conduct peer exchanges annually as a form of workforce development.
2. Document and convey findings from each peer exchange.

Proposed Research Activities (work steps)

The FHWA regularly conducts peer exchanges to promote pavement management practices. This effort supports those activities and provides specific topics that might be considered. It is suggested the FHWA sponsor a minimum of one peer exchange annually for 6 years.

Desired Products

- Peer exchanges.
- Peer exchange reports.

Estimated Timeframe and Cost

Cost: \$75,000 per year, \$450,000 total

Duration: 6 years

TRAINING ACTION ITEMS

8A: Develop Pavement Management Training

Category of Work (Research, Training, Deployment, etc.): Training

Short- or Long-Term? Short-term

Description/Items to Be Addressed

Develop training on:

- Pavement data collection strategies.
- Basic statistics.
- Data quality management plans and how to use them.
- Equipment calibration and certification practices.
- Other data quality topics, including data sampling and reviewing processes, error resolution, pre-processing techniques to address data issues, rater certification.
- Data science applications for pavement management.
- SQL and other database programming skills.
- Pavement performance modeling, including data types, model types, & statistical acceptance.
- Use of structure data and other information to support project & treatment selection.
- Role of pavement management champions.

Primary Objective

1. Develop training materials to support pavement management practitioners.

Proposed Research Activities (work steps)

This effort addresses training topics identified by pavement management practitioners. A combination of in-person and online training materials are expected to be developed. The development may take place through the National Highway Institute (NHI) or through another contract mechanism.

Desired Products

A comprehensive set of detailed training materials available through a combination of in-person and online learning.

Estimated Timeframe and Cost

Cost: \$750,000

Duration: 5 years

8B: Conduct Workshops to Share Well-Developed Documents

Category of Work (Research, Training, Deployment, etc.): Training

Short- or Long-Term? Short-term

Description/Items to Be Addressed

Conduct workshops to share practices on:

- How to use GPR data for project selection.
- Use of TSDD data in decision trees and performance models.
- Data integration.
- Using pavement management for life cycle planning.
- The development and use of leading performance measures.

Primary Objective

1. Conduct regional workshops to promote the use of pavement management reference documents.

Proposed Research Activities (work steps)

This effort promotes the conduct of regional pavement management workshops on a periodic basis to promote practice documents as they become available. The regional workshops will be organized and conducted by a contractor responsible for arranging travel, teaching the technical material, and facilitating discussion. A short summary report will be prepared after each workshop that identifies the workshop participants and any issues that arose. The estimate assumes 4 regional workshops will be held in a year and that the cycle will be repeated in 5 of the 10 years covered by the *Roadmap*.

Desired Products

4 Regional workshops held 5 times over the 10-year period.

Estimated Timeframe and Cost

Cost: \$200,000 each year, \$1,000,000 for 5 years of workshops **Duration:** 5 years

8C: Develop and Implement a Peer-to-Peer Training Program

Category of Work (Research, Training, Deployment, etc.): Training

Short- or Long-Term? Long-term

Description/Items to Be Addressed

Develop and implement a Peer-to-Peer training program.

Primary Objectives

1. Develop a peer-to-peer training program that enables practitioners to share practices.
2. Implement and administer the program.

Proposed Research Activities (work steps)

This program provides travel funds for State DOT practitioners to travel to other States to share practices and explain how they have addressed specific challenges. Under this program, a Pavement Management Engineer from a State DOT with well-established practices will receive travel funding to spend up to 2 days with a selected agency struggling with a particular issue. If the issues that will be addressed is a challenge to neighboring State DOTs, representatives from those States may also be invited to participate in the training session. A contractor will administer the program for the FHWA and attend the training.

Desired Products

An annual peer-to-peer training program administered by a contractor.

Estimated Timeframe and Cost

Cost: \$250,000

Duration: 5 years

8D: Redesign the FHWA's Pavement Management User's Group

Category of Work (Research, Training, Deployment, etc.): Training

Short- or Long-Term? Short-term

Description/Items to Be Addressed

Redesign the FHWA's PMS User's Group to focus more on training.

Primary Objectives

1. Redesign the FHWA's Pavement Management User's Group to provide training on technical issues relevant to pavement management practitioners.
2. Conduct User's Group webinars at least 4 times per year for 10 years.

Proposed Research Activities (work steps)

The FHWA has established a Pavement Management User's Group that conducts periodic webinars to promote pavement management practices.

Desired Products

Quarterly webinars on pavement management.

Estimated Timeframe and Cost

Cost: \$500,000

Duration: 10 years

8E: Conduct Pavement Management Guide Book Club Sessions

Category of Work (Research, Training, Deployment, etc.): Training

Short- or Long-Term? Long-term

Description/Items to Be Addressed

Conduct book club sessions on the updated Pavement Management Guide when finished.

Primary Objectives

1. Promote the use of the updated Pavement Management Guide.
2. Build skills among pavement management practitioners.

Proposed Research Activities (work steps)

A separate research activity involves updating the 2012 Pavement Management Guide to reflect current practices and technology. When the Guide is completed, it is suggested that a Book Club be conducted via a series of webinars to promote familiarity with the Guide and to develop practitioners' skills. The Book Club will be modeled after previous successful Book Clubs conducted to promote the 2012 Pavement Management Guide and the 2020 Transportation Asset Management Guide.

Desired Products

A series of webinars to promote the updated Pavement Management Guide.

Estimated Timeframe and Cost

Cost: \$150,000

Duration: 12 months

8F: Conduct Workshops at Conferences

Category of Work (Research, Training, Deployment, etc.): Training

Short- or Long-Term? Long-term

Description/Items to Be Addressed

Conduct workshops on the updated Pavement Management Guide at conferences.

Primary Objective

1. Support skill development among pavement management practitioners.

Proposed Research Activities (work steps)

The International Pavement Management Conference provides an opportunity to share practices among peers. Immediately prior to the conference, there is traditionally an opportunity to conduct workshops to present results from recently completed research or to deliver training courses. Under this activity, these efforts are supported through the leadership of the FHWA and the TRB Technical Committees. The costs for the workshops are typically covered under a research project or on a voluntary basis so no costs are estimated for this effort.

Desired Products

Workshop sessions at each International Pavement Management Conference.

Estimated Timeframe and Cost

Cost: \$0

Duration: 10 years

8G: Establish a Pavement Management Leadership Academy

Category of Work (Research, Training, Deployment, etc.): Training

Short- or Long-Term? Long-term

Description/Items to Be Addressed

Incorporate updated training materials into a Pavement Management Leadership Academy to build skills & raise pavement management's profile.

Primary Objectives

1. Enhance the skills of pavement management practitioners.
2. Raise the stature of pavement management as a profession.

Proposed Research Activities (work steps)

Following the development of the training courses outlined in a separate Action Item Statement, this effort organizes the content into a Pavement Management Leadership Academy. In addition to teaching technical skills associated with pavement management, training content will develop leadership and interpersonal skills. Upon successful completion of the Leadership Academy, pavement management practitioners will be awarded a Certificate of Completion recognizing their accomplishments. The Leadership Academy will consist of both independent and face-to-face lessons, consisting of approximately 40 hours of instruction. The costs assume the Pavement Management Leadership Academy will be offered once a year for 4 years.

Desired Products

Pavement Management Leadership Academy

Estimated Timeframe and Cost

Cost: \$500,000

Duration: 4 years

9D: Create On-The-Job and Just-In Time Training Materials

Category of Work (Research, Training, Deployment, etc.): Training

Short- or Long-Term? Short-term

Description/Items to Be Addressed

Create on-the-job and just-in-time training materials.

Primary Objectives

1. Enhance the skills of pavement management practitioners, including local agencies.
2. Create short, practical training materials that are available online to support pavement management demands.

Proposed Research Activities (work steps)

To support State and local pavement management practitioners, short, practical training materials (e.g., job aids) will be developed to support specific aspects of pavement management. The training will consist of YouTube videos, podcasts, how-to-guides, checklists, and other materials to enable practitioners to apply technical concepts.

Desired Products

A collection of short, practical job aids to help pavement management practitioners perform their responsibilities.

Estimated Timeframe and Cost

Cost: \$600,000

Duration: 4 years

10F: Develop a New Technology Demonstration Program For University Students

Category of Work (Research, Training, Deployment, etc.): Training

Short- or Long-Term? Long-term

Description/Items to Be Addressed

Develop and support an equipment & new technology demonstration program at the university level to train students.

Primary Objective

1. Promote interest in pavement management at the university level.

Proposed Research Activities (work steps)

Pavement management practitioners are often forced to learn necessary skills while on the job since university curriculums do not generally teach pavement management concepts. One way to generate interest in pavement management is to provide university students with the opportunity to apply new and emerging technology to address the types of challenges that pavement managers face. This effort creates the framework for a new technology demonstration program for State DOTs and universities.

Desired Products

Framework for a State DOT and university partnership in which new and emerging technology are used to support problems in courses offered under the Civil Engineering curriculum.

Estimated Timeframe and Cost

Cost: \$300,000

Duration: 18 months

12B: Create Sharable Materials to Promote Pavement Management

Category of Work (Research, Training, Deployment, etc.): Training

Short- or Long-Term? Short-term

Description/Items to Be Addressed

Create sharable materials that convey pavement management messaging for the public that can be placed on an agency's website.

Primary Objective

1. Develop materials that can be used by multiple agencies to promote pavement management concepts.

Proposed Research Activities (work steps)

One of the challenges to the implementation of pavement management project suggestions is public perception. Unless the concept of pro-active preservation is explained, elected officials and members of the public question decisions when preventive treatments are applied to roads in relatively good condition. Under this effort, a short, 5- to 10-minute animated video will be produced to convey pavement management concepts in a way that is easy to understand. In addition, print materials will be developed in a generic format that can be customized by an individual agency for use during public meetings, during public outreach sessions, or on the agency's website.

Desired Products

- A short video promoting pavement management concepts.
- Modifiable print materials that agencies can use to promote pavement management concepts.

Estimated Timeframe and Cost

Cost: \$150,000

Duration: 12 months

13A: Document Benefits to Consistent Funding for Pavement Management

Category of Work (Research, Training, Deployment, etc.): Training

Short- or Long-Term? Short-term

Description/Items to Be Addressed

Document success stories where consistent funding for pavement management updates has led to improvements in network conditions and contrast this with agencies where funding has not been consistent.

Primary Objective

1. Quantify the benefits to consistent funding to support pavement management.

Proposed Research Activities (work steps)

To demonstrate the importance of consistent funding to support data collection efforts and the acquisition of software tools, a case study will be developed illustrating the benefits realized by agencies that have invested consistently in pavement management efforts. Where possible, the benefits will be quantified. To develop the case study, the following activities will be conducted:

- Identify candidate agencies for the case study.
- Conduct interviews with the candidate agencies.
- Select a maximum of 5 agencies.
- Conduct detailed interviews with the selected agencies.
- Document the case studies in a report of no more than 20 pages.

Desired Products

Case study report.

Estimated Timeframe and Cost

Cost: \$150,000

Duration: 12 months

TOOL DEVELOPMENT ACTION ITEMS

4F: Development of Predictive Performance Models for Asset Management

Category of Work (Research, Training, Deployment, etc.): Tool Development

Short- or Long-Term? Short-term

Description/Items to Be Addressed

Develop a tool that can be used to predict pavement performance using either LTPP data as the default or agency data.

Primary Objectives

1. Develop a tool to predict pavement performance using functional or structural metrics and data extracted from LTPP, State DOT databases, or National Performance metrics to ensure consistency in pavement performance modeling across different FHWA applications.
2. Promote the use of the tool.

Proposed Research Activities (work steps)

The LTPP program has proposed a project to develop a pavement performance tool to determine the effects of loading, environment, material properties, and variability; construction quality; design features; and maintenance levels. The tool will be capable of analyzing data at the network, State, or section levels. The research objectives will be achieved through the following activities:

- Summarize the features to be addressed in the tool.
- Establish a framework for modeling pavement performance.
- Develop a prototype to test the framework using different data sets.
- Finalize the prototype based on findings from the initial test.
- Identify State DOTs to beta test the tool using State DOT data.
- Conduct a beta test of the tool using LTPP and other national data sets.
- Document the results from the beta testing.
- Finalize the tool development based on the findings.
- Create deployment materials for promoting the use of the tool among practitioners.

Note: This action item statement is based on LTPP-PROJ-0000237, Development of Predictive Pavement Performance Models for Asset Management.

Desired Products

- Pavement performance modeling tool.
- Deployment materials to promote its use.

Estimated Timeframe and Cost

Cost: \$750,000

Duration: 36 months

11A: Develop a Consistent Automated Data Checking Tool

Category of Work (Research, Training, Deployment, etc.): Tool Development

Short- or Long-Term? Short-term

Description/Items to Be Addressed

Develop a consistent, automated data checking tool to evaluate submittals by data vendors in accordance with a DQMP.

Primary Objectives

1. Develop an automated data checking tool that can be used by State DOTs.

Proposed Research Activities (work steps)

To support the data acceptance tasks normally conducted by an agency that contract out automated pavement management survey, this effort will develop a data checking tool that automates the review of several typical components of a Data Quality Management Program (e.g., reasonableness and completeness of the data). The tool will be developed to be used with data collected by most data collection vendors. This will be accomplished through the following activities:

- Synthesize the formats used by vendors for delivering data.
- Identify standard data acceptance tests that can be applied.
- Develop a generic data checking tool that is flexible enough to accommodate data files from different equipment vendors.
- Conduct beta testing of the software using agency data from several agencies.
- Develop deployment materials on the use of the software tool.

Desired Products

Automated data checking tool.

Estimated Timeframe and Cost

Cost: \$300,000

Duration: 24 months

11B: Create Tools to Access Older Data Collection Images

Category of Work (Research, Training, Deployment, etc.): Tool Development

Short- or Long-Term? Long-term

Description/Items to Be Addressed

Software tools for accessing images from data collection efforts after vendors no longer provide access, which is generally 5 years.

Primary Objective

1. Developing software tools that allow long-term access to pavement images and sensor data from data collection efforts.

Proposed Research Activities (work steps)

Many transportation agencies contract out data collection services. Most of the time, the image and sensor data are only supported through vendor-specific software platforms. This proposed research investigates the potential to develop tools to ensure long-term access to image data to support pavement management demands. This will be accomplished through the following activities:

- Synthesize the different image formats used by vendors using different technologies.
- Document how agencies use image data, especially older images.
- Explore existing approaches to standardize image formatting being conducted by the FHWA and AASHTO.
- Develop a generic software tool that is flexible enough to accommodate data files from different equipment vendors to generate information for agency use at no cost to transportation agencies.
- Conduct beta testing of the software using agency data from different vendors.
- Develop deployment materials on the use of the software tool.

Desired Products

- Software tools that agencies can use to access image and sensor data from automated data collection equipment.
- User's Guide for the software tool.

Estimated Timeframe and Cost

Cost: \$500,000

Duration: 24 months

11C: Support Vendor Modifications to Pavement Management Tools

Category of Work (Research, Training, Deployment, etc.): Tool Development

Short- or Long-Term? Long-term

Description/Items to Be Addressed

Support vendor software modifications to better enable an LCP analysis and the use of next-generation pavement performance measures.

Primary Objective

1. Encourage software suppliers to modify pavement management software tools to support advancements in the use of next-generation performance measures, the use of new technology (e.g., TSDD data), and other agency demands.

Proposed Research Activities (work steps)

This effort demands no public funding but encourages on-going private-sector investment in pavement management software to incorporate new developments in pavement management into their analysis tools.

Desired Products

Pavement management software tools that take advantage of advancements in the state of practice.

Estimated Timeframe and Cost

Public Cost: \$0

Duration: 10 years
