Appendix C – Research Topics

Broad Agency Announcement (BAA)

Office of Acquisition and Grants Management

Federal Highway Administration

Research Initiatives in Support of FHWA's Office of Infrastructure Research and Development (HRDI)

Note: Concept papers may be submitted at any time up to the closing date of the research topic.

Advanced Digital Construction (ADC)			
Topic Number	**Title**	**Closing Date for Concept Papers**	**See Note Below Table**
HRDI-ADC-12	Bid Items Standard Assessment [Reissued]	45 days after posted on SAM.gov	C
HRDI-ADC-13	Advancing BIM for Infrastructure National Strategic Roadmap Update	45 days after posted on SAM.gov	C

Transportation Resilience and Safety (TRS)			
Topic Number	**Title**	**Closing Date for Concept Papers**	**See Note Below Table**
HRDI-TRS-07	Pavement Friction Assessment Using Automated and Connected Vehicle Data	45 days after posted on SAM.gov	E
HRDI-TRS-08	Pavement Preservation Treatments to Provide Higher Level Friction	45 days after posted on SAM.gov	E
HRDI-TRS-09	Highway Resilience Measure Selection Tool	45 days after posted on SAM.gov	E

Transportation Resilience and Safety (TRS) (Continued)			
Topic Number	**Title**	**Closing Date for Concept Papers**	**See Note Below Table**
HRDI-TRS-10	Evaluation of Non-contact Friction and Microtexture Systems	45 days after posted on SAM.gov	E
HRDI-TRS-11	Develop Pavement Structure Evaluation Procedures for Existing Asphalt Pavements Identified to Receive a High Friction Surface Treatment	45 days after posted on SAM.gov	E
HRDI-TRS-12	Influence of Macrotexture and Water Film Thickness on Skid Resistance and Pavement Safety	45 days after posted on SAM.gov	F

Enhanced Pavement Management (EPM)			
Topic Number	**Title**	**Closing Date for Concept Papers**	**See Note Below Table**
HRDI-EPM-04	Update and Implement the Next-Generation Asset Management Methodologies [Reissued]	45 days after posted on SAM.gov	I
HRDI-EPM-05	Assessing the Impact of TPM PM2 and AMP on Asset Management and Programming	45 days after posted on SAM.gov	G
HRDI-EPM-06	Incorporating Nondestructive Evaluation Technologies into Pavement Asset Management	45 days after posted on SAM.gov	C

Bridge Preservation and Management (BPM)			
Topic Number	**Title**	**Closing Date for Concept Papers**	**See Note Below Table**
HRDI-BPM-05	Digital As-Built Data for Improved Bridge Management	45 days after posted on SAM.gov	E
Pavement Modeling and Performance (PMP)			
Topic Number	**Title**	**Closing Date for Concept Papers**	**See Note Below Table**
HRDI-PMP-02	PEM Durability Test Thresholds and Design Adjustment	TBA	

As specified by note in the table above, the following are the expected funding ranges for the corresponding research topics and should be considered in the preparation of concept papers and proposals accordingly. Innovative concept papers and proposals with high technical merit and high value that exceed expected funding ranges must clearly identify items that exceed the range.

The Government reserves the right to select for award any, all, part, or none of the proposals received in response to this announcement. The Government will consider the overall availability of funding for allocations or awards selected.

Note A: $50,000 - $75,000

Note B: $155,000 - $170,000

Note C: $150,000 - $200,000

Note D: $200,000 - $300,000

Note E: $250,000 - $350,000

Note F: $250,000 - $400,000

Note G: $350,000 - $500,000

Note H: $450,000 - $650,000

Note I: $550,000 - $700,000

Note J: $650,000 - $750,000

Advanced Digital Construction

Topic: HRDI-ADC-12

Title: Bid Items Standard Assessment

Modern practices and technologies have brought compelling opportunities to FHWA and state agencies for utilizing agency-wide asset data that were not possible in the past. A critical aspect to ensure success is the development and adoption of data standards to ensure data preservation and exchange.

Utilizing uniform bid data, open data exchange standards, and data-linking approaches, a unit bid item standard ensures that business inefficiencies associated with information loss are minimized and the data and information chain is preserved for all subsequent users and their needs.

FHWA investigated the impacts of Material Source Mergers and Acquisitions (M&A) on Competition (HRT-22-081). The research was inconclusive in determining trends associated with unit prices and impacts on competition in the materials supply chain; and researchers did not identify any clearly defined, quantitative evidence of M&A impacts on pricing. A significant hurdle identified during the research was lack of uniformity and inconsistent application of unit bid item data formats, descriptions, selection, and use across state agencies, i.e. lack of standardization.

Additionally, FHWA's OIG has initiated audits on topics that rely on unit bid items and costs in the areas of competition, change orders, and engineers estimates. And there has been recent interest by the current administration on a standardizing bid items through outreach with AASHTO.

A bid item standard can provide many benefits and improve the above items, including:

1. Provide consistent project planning, delivery, and management of multiple diverse projects and contracts.

2. Provide a common description and structure to reduce efforts needed to prepare and review estimates, bids, change orders, and competition impacts; and improve accuracy.
3. Provide consistency and uniformity to facilitate data mining, comparisons, and evaluating state, local, regional, and national trends, and efficient and effective cost controls.
4. Provide improved data integration and analysis of data from various projects, leading to improved decision making and strategic planning.
5. Provide ability to benchmark performance across different projects and contractors and help identify areas for improvement.
6. Provide data exchange and lifecycle needs for successful application of BIM for Infrastructure and digital project delivery initiatives.
7. Provide the ability to compare costs across jurisdictional lines.

Goals of this research are to assess, examine the considerations, and layout the steps needed to develop and implement a national highway construction unit bid item data standard in the U.S. The assessment will document the benefits and needs with priorities, identify areas of pushback and provide methods and strategies to address, and provide development and implementation strategies and plans. The result will lay the groundwork and provide a path forward to facilitate the adoption and use of a national unit bid item standard.

Topic: HRDI-ADC-13

Title: Advancing BIM for Infrastructure National Strategic Roadmap Update

FHWA's 2021 National Strategic Roadmap (NSR) (1,2) established a decade-long national vision for BIM for Infrastructure. Technical, organizational, and policy conditions have evolved substantially since publication. Since publication, the industry has advanced rapidly — with new open standards, maturing data environments, expanded use of digital as-builts, digital twins, reality capture, and AI/ML workflows. State DOTs have piloted model as the legal document processes and integrated asset management. Needed is a consolidated, evidence-based assessment of national progress against the original NSR and an updated strategy that reconciles advanced standards, vendor capability, State DOT pilots, and funding opportunities. FHWA

seeks research that diagnoses progress, characterizes gaps and risks, and produces a balanced, implementable update/revision to the NSR that accelerates benefit realization while minimizing disruption to ongoing initiatives. Resulting in an up-to-date, evidence-based national strategy that reflects these advancements, lessons learned, policy/funding changes, and evolving stakeholder readiness.

Goals of this research are to assess national and State-level progress against the 2021 NSR maturity milestones and recommended improvements and updates to the NSR. Efforts should consider the following elements:

- Baseline assessment of BIM maturity across State DOTs and gap analysis.
- Standards adoption and interoperability.
- Data governance, quality assurance, and secure multi-stakeholder exchange.
- Digital as-built requirements and reality capture progress.
- Contracting/procurement practices, including model as legal document pilots
- BIM, digital twin, asset management integration
- Assess national and State level progress against the 2021 NSR milestones.
- Identify gaps, barriers, accelerators, and high-value use cases for highways and bridges.
- Synthesize an updated and adaptable NSR reflecting current technology, policy, and evolving stakeholder readiness.
- Recommend phased adoption scenarios that maximize benefits while minimizing disruption to ongoing implementations.

Desired outcome is an updated nationally relevant BIM NSR that integrates 2021–present advancements, accelerates adoption, and strengthens interoperability, ROI, and stakeholder alignment for the U.S. highway and bridge sector.

1. References:U.S. Department of Transportation. 2021. "Advancing BIM for Infrastructure: National Strategic Roadmap." National Transportation Library. Accessed Feb 2, 2026. https://rosap.ntl.bts.gov/view/dot/56953.

2. Federal Highway Administration, Advancing BIM for Infrastructure: National Strategic Roadmap, FHWA-HRT-21-064, (Washington, DC: 2021) https://doi.org/10.21949/1521637

Transportation Resilience and Safety

Topic: HRDI-TRS-07

Title: Pavement Friction Assessment Using Automated and Connected Vehicle Data

Traditional methods of evaluating pavement friction (like locked-wheel skid testers or friction trailers) are costly, infrequent, and labor-intensive. They often fail to capture dynamic or localized friction changes. Meanwhile, Automated Vehicles (Avs) and Connected Vehicles (CVs) generate massive streams of high-resolution driving dynamics data (e.g., ABS/ESC activations, yaw rates, tire slip, braking behavior), which could signal friction variations in real-time.

This project proposes to develop and evaluate a novel framework for utilizing sensor data from AVs for enhanced pavement surface friction evaluation and management. By analyzing this wealth of data, including metrics like ABS/ESC activations, yaw rates, and tire slip, this study aims to extract comprehensive insights into pavement friction characteristics across entire road networks, enabling more proactive and effective pavement friction management strategies. This research will develop a comprehensive framework to estimate and predict pavement friction using AV/CV telemetry by (1) conducting a literature review and gap analysis of existing sensing and estimation methods; (2) identifying and prioritizing key vehicle data features (e.g., wheel slip, accelerations, ABS/braking events, steering, wheel speeds, tire pressure, and environmental indicators); (3) developing and comparing statistical and machine learning models to infer friction from telemetry; (4) validating and benchmarking models against controlled DOT friction test tracks and inclement weather ground truth datasets; and (5) prototyping a real time friction mapping system that ingests live telemetry, produces geospatial friction estimates for agency workflows (via APIs, tiles, and alerts), and evaluates latency, scalability, and privacy safeguards.

Topic: HRDI-TRS-08

Title: Pavement Preservation Treatments to Provide Higher Level Friction

Pavements are designed, constructed, and maintained to be durable, cost-effective, and safe. Pavement preservation treatments have traditionally been primarily focused on maintaining and

preserving the durability integrity of pavements. It is critical for the pavement friction to also be considered as maintaining the appropriate level of pavement friction is critical for safe driving. Due to the higher tire pavement surface interface stresses that occur at locations such as horizontal curves, steep grades, and intersections (i.e. high friction demand road segments), the road surface experiences greater polishing than an adjacent flat tangent section of road which results in lower pavement friction. High Friction Surface Treatments (HFST) is a proven safety countermeasures to mitigate these lower friction conditions. HFST per AASHTO Standard MP 41 involves the application of Calcined Bauxite aggregate to the pavement using a polymer binder to provide a relatively very high pavement friction surface at existing or potentially high crash areas. Many reports have documented the success of HFST significantly reducing crashes.

Information is becoming available within the US that this HFST level of friction may not be needed to meet the friction demand/safety of many existing road segments. In other words, a more "mid-level higher" friction would meet the safety requirements and there are longer segments of road that this would apply to (i.e. not isolated "spot" locations). Table 13 in report FHWA SA-23-006 *Characterizing Road Safety Performance Using Pavement Friction* provides insight into this concept with different friction threshold levels for different friction demand site categories. It is recognized that the friction value within this FHWA report is from a continuous pavement friction measurement (CPFM) system that is compliant with AASHTO TP 143 which can measure friction continuously through the high friction demand road segments (curves/intersections), thus quantifying and characterizing friction in a context that has been related to safety as reported within this FHWA report.

HFST installation and materials are specialized when compared with conventional pavement treatments which results in a higher initial cost. This cost element along with the understanding that the HFST friction level is not required at all locations to meet safety needs introduces the need for a "mid-level higher" friction treatment. In other words, within conventional pavement materials engineering, there are different quality levels of pavement materials for different conditions, applying that same concept to pavement preservation treatments for friction purposes, "friction toolbox" is desired.

The objective of this project is to primarily investigate other alternative aggregates, manufactured and natural (such as lightweight aggregates, slag, taconite, etc.) to be used with pavement preservation treatments to provide higher-friction surfaces that meet the safety needs of the road segment over the life of the pavement surface treatment. If binder

modifications/optimization from standard binders is needed this is to be investigated also. Pavement surface characteristics and material assessment will include those related to macrotexture and microtexture. Cost effectiveness is to be explored and will include costs and benefits from pavement management and safety management perspective. This project outcomes could result in identifying cost effective higher-friction pavement treatments (type and materials) which can be utilized nationally, regionally, or locally, friction toolbox, to meet the friction related safety need.

Topic: HRDI-TRS-09

Title: Highway Resilience Measure Selection Tool

Many Departments of Transportation (DOTs) are interested in resilience but are not able to implement resilience measures into roadway infrastructure damaged by a natural disaster and extreme events because their design standards may not include resilience measures and/or the DOT is uncertain which measures could be appropriate to protect their asset against a future similar disaster event. Many DOT personnel are performing multiple duties and therefore do not have time to read the reports that detail resilience strategies. They have expressed a desire for an easily accessible resource to help them quickly identify potential solutions.

This project will develop a web-based selection tool (similar to the USEPA's Resilient Strategies Guide) to help users filter through a list of commonly used resilience measures that can be implemented into different types of highway assets to protect against different types of natural hazards. The information about each resilience measure will include a photo or depiction and concise description of the measure, relevant natural hazards, caveats about use/effectiveness, low-medium-high cost magnitude, potential permitting requirements, and links to additional resources for more information.

The project team will need to develop and test a web-based tool using data provided by FHWA. Testing should ensure the tool is compatible with commonly used browsers and devices, including mobile devices. Throughout the tool development process, the team will work with FHWA's IT department to ensure compliance with USDOT requirements and install the final tool to link to the FHWA Emergency Relief website.

Topic: HRDI-TRS-10

Title: Evaluation of Non-contact Friction and Microtexture Systems

FHWA has been investigating and finding value in continuous pavement friction measurement for safety analysis. These data include non-contact sensor data for macrotexture assessment, but rubber tire response data for microtexture assessment. Rubber tire response data include water and rubber tire in contact with the pavement and measurement of resultant forces. It is desirable to move to a non-contact assessment/measurement for such reasons as testing efficiency (water is a major limiting factor on production along with tire wear) and comparable systems (rubber tire response systems are comparable to the same configuration of test method thus making a challenge to compare to different rubber tire response systems). This will significantly reduce the cost of the data which will facilitate friction-based safety analysis.

An increasing number of non-contact friction measurements (including laser-based or image-based techniques) are becoming available, from DOT fleet vehicles equipment and more recently from drone and satellite images. Several manufacturers/system integrators/researchers are developing non-contact friction and microtexture assessment/measurements due to the increased interest in frictions relationship with safety. The feasibility of correlating non-contact friction and microtexture assessment/measurements directly to crashes (safety performance analysis) is to be explored before or in conjunction with correlating with rubber tire response systems. This project is to evaluate existing non-contact friction and microtexture assessment/measurement systems for use in safety analysis. The project will include an evaluation of the friction model performance in addition to the examination of data formats and technologies that would best evaluate the pavement friction and microtexture levels.

Topic: HRDI-TRS-11

Title: Develop Pavement Structure Evaluation Procedures for Existing Asphalt Pavements Identified to Receive a High Friction Surface Treatment

Many agencies have experienced great value from High Friction Surface Treatment (HFST) installations. Some asphalt pavements that received HFST have failed prematurely. There are

two failure types that are challenging and objective/reasonable strategies to address have not been developed:

- Type 1: Underlying asphalt pavement delaminates/shears.
- Type 2: Moisture related accelerated failures.

These failure types have resulted in some agencies reducing HFST installations, thus addressing them is expected to increase long term performance of HFST.

The objective of this project is to conduct a targeted research project investigating premature failures at HFST locations and to develop robust evaluation procedures to enhance long-term performance. Specifically, the project will address the above challenging failure modes for which practical, objective strategies have not yet been established. FHWA Office of Safety has published a High Friction Surface Treatment Site Selection and Installation Guide. This document will be used as background information but does not specifically address these two failure types.

The ultimate objective is to develop pavement structure, durability, and moisture-susceptibility evaluation procedures for existing asphalt pavements designated to receive HFST, enabling more reliable performance, informing design and maintenance practices, and reducing the need for premature HFST removals or replacements.

Topic: HRDI-TRS-12

Title: Influence of Macrotexture and Water Film Thickness on Skid Resistance and Pavement Safety

Skidding crashes are a major concern in assessing pavement safety on various roadway categories. According to the Federal Highway Administration, inadequate pavement texture properties, particularly macrotexture, can lead to serious injuries and fatalities, especially during wet conditions (1). Macrotexture is defined by the deviation of a pavement surface and refers to the larger-scale surface texture, determined by the size, shape, gradation, and spacing of aggregate in asphalt concrete pavement (2). Studies have shown that pavement surface macrotexture significantly influences wet crashes by playing an essential role in facilitating water drainage and improving friction and traction at the pavement-tire interface (3). When macrotexture channels water away effectively, the tire can maintain friction with the road rather

than riding on a water film, reducing the risk of sudden loss of traction at typical driving speeds on wet surfaces. This texture also influences wet grip and braking performance, as better drainage helps sustain longitudinal and lateral forces during deceleration, braking, and cornering. Inadequate macrotexture can permit a persistent water film, elevating hydroplaning potential, while excessive texture may increase tire wear or noise so optimizing macrotexture is key to balancing safety, durability, and ride quality in wet conditions.

This study will investigate how pavement macrotexture and the thickness of the water film beneath tires jointly influence skid resistance and overall safety. By conducting controlled wet-road condition experiments across a range of macrotexture depths, surface conditions, and pavement types, the research will quantify how increases in macrotexture improve drainage and maintain tire-pavement contact under varying water films, while also identifying thresholds where not adequate texture begins to degrade friction and cause unsafe conditions. Advanced laboratory instrumentation such as three-wheel polishing device, dynamic friction testers, and laser scanners—will be used to capture interactions between water film thickness, texture depth, and tire grip. The study aims to develop predictive models and practical guidance for texture specifications and pavement maintenance strategies that enhance skid resistance and safety in wet conditions across urban and rural roadways.

References:

1. Ergun, M., Iyinam, S. and Iyinam, A.F. Prediction of road surface friction coefficient using only macro- and microtexture measurements. *Journal of Transportation Engineering*, 2005. 131(4), 311–319.
2. Flintsch, G.W., de León, E., McGhee, K.K., and Al-Qadi, I.L., Pavement Surface Macrotexture Measurement and Applications. *Journal of the Transportation Research Board*, 2003. Volume 1860, 168-177.
3. Najafi, SH., Flintsch, G. W., and Medina, A. 2017. Linking roadway crashes and tire–pavement friction: a case study. Linking roadway crashes and tire–pavement friction: a case study: International Journal of Pavement Engineering: Vol 18, No 2 https://www.tandfonline.com/doi/full/10.1080/10298436.2015.1039005

Enhanced Pavement Management

Topic: HRDI-EPM-04

Title: Update and Implement the Next-Generation Asset Management Methodologies

Transportation Asset Management (TAM) is a systematic, data-driven approach that assesses asset conditions and funding needs, applies engineering and economic analysis, and guides the selection of optimal investment strategies and policies to achieve agency goals. Integrating Cross Asset Tradeoff Analysis (CATA) is essential for enhancing decision-making processes, enabling agencies to allocate resources more efficiently, break down asset class silos, plan for different infrastructure-wide scenarios, manage risks, and communicate decisions transparently to stakeholders. By incorporating trade-off analysis across asset classes, agencies can achieve better outcomes of total infrastructure performance, ensure optimal resource distribution as a highway infrastructure system, and make more informed investment decisions.

In 2015, FHWA initiated research as a two-phased effort titled "Identification of Effective Next-Generation Pavement Performance Measures and Asset Management Methodologies to Support MAP-21 Performance Management Requirements". Publication NO. FHWA-HRT-23-102. The research proposed a transportation asset management methodology to help transportation agencies manage their highway infrastructure as a system, rather than a network of individual asset classes. This method can be used by the FHWA Tradeoff Analysis for Multi-asset Performance Objectives (TA-MAPO) tool, serving as a key component in the TAM process. It provides a comprehensive solution for conducting tradeoff analysis, identifying the optimal set of projects that maximize the total performance criteria across all included asset classes. These findings can assist in setting informed targets that are considerate of needs and optimal projects across asset classes.

Highway physical assets are maintained over their lifecycle through appropriately timed sequence of treatment actions. Section 1106 of MAP-21 defines 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 lifecycle of the assets at minimum

practicable cost.'' Implicit in this is that if any of the identified strategic sequence of actions is delayed, the asset will likely require a more intensive and costlier treatment in later years and the lifecycle cost will increase. However, most current trade-off analysis methodologies and tools do not have a feedback loop to the individual asset management systems or consider the cost of delaying a treatment action. They also fail to consider how delaying a treatment action will alter the asset's future sequence of treatment actions. Moreover, trade-off analyses must account for how various asset classes impact road users and the broader transportation system. When certain asset classes (such as pavements) have traditionally not explicitly included some benefit types—such as safety or mobility—in the benefits quantification, while others do, it becomes difficult to use benefit-cost ratios (BCR) for trade-off analysis or project prioritization across different asset classes.

Challenges and Gaps

- Proposed Transportation Asset Management Methodology: The proposed Transportation Asset Management Methodology (TAMM) needs to be reviewed to determine what data it requires from individual asset management systems. This assessment should also identify each system's analytical capabilities for providing that data, and propose solutions—like system enhancements, external analysis, or surrogate inputs—where gaps exist.
- Tool Integration: Enhancements to the TA-MAPO tool may be required to enable seamless integration with existing systems, ensuring that it can be effectively adopted by various State Departments of Transportation (DOTs).
- Training and Documentation: Adequate training and documentation are essential for practitioners to effectively implement the new methodologies and tools.

Output and Outcome

The proposed plan aims to deliver the following outputs and outcomes:

Phase 1

- Enhanced TAMM: Revise and enhance the current methodology to incorporate the effects on users and the transportation system in trade-off analysis, as well as the costs and future maintenance sequence impacts of delayed treatments.

- Improved Tool Functionality: Upgrades to the TA-MAPO tool to enable better integration and functionality, facilitating more effective decision-making.

Phase 2

- Comprehensive Training: Conducting training sessions and workshops to introduce new methodologies and tools, including hands-on exercises and demonstrations.
- Ongoing Support and Refinement: Providing continuous support and refinement of the methodologies and tools to ensure their successful adoption and implementation across various transportation agencies.

By addressing the challenges of Integrating Cross Asset Tradeoff Analysis (CATA) and delivering the subsequent outputs, the plan aims to significantly enhance the efficiency and effectiveness of transportation asset management, ultimately leading to improved resource allocation and investment decisions.

Topic: HRDI-EPM-05

Title: Assessing the Impact of TPM PM2 and AMP on Asset Management and Programming

FHWA has advocated the implementation of Transportation Asset Management (TAM) and Transportation Performance Management (TPM) frameworks by State DOTs. While the FHWA mandates states to submit data and set performance targets on infrastructure condition under the TPM PM2 framework, agencies primarily rely on their individual asset management systems for actual project programming and decision-making. FHWA also requires DOTs to submit Asset Management Plans (AMP) outlining how assets will be managed over 10 years. Ideally, TPM PM2 and AMP requirements would align with and add value to the DOT's internal programming systems and TAM, ensuring federal reporting remains synchronized with the agency's primary decision-making tools and that federal compliance provides genuine value.

TAM has fostered a coordinated and holistic approach to managing highway networks as connected systems rather than isolated asset classes. Reported benefits include lower

maintenance costs and better investment prioritization. However, comprehensive evaluation is needed to determine the level of implementation, assess real-world impacts and cost savings across multiple states, and identify gaps and challenges that limits full realization of the benefits. Furthermore, agencies have learned over the years what performance measures work the best for them and they may differ from TPM or AMP requirements. It is unclear whether and how PM2 positively influences TAM to optimize asset life cycles, enhance service delivery, or minimize asset lifecycle costs. To what extent are agencies considering PM2 as part of their asset management programs, and how can the two be more effectively aligned?

This project will conduct a look-back analysis to assess the impacts of TAM and TPM implementation across selected State DOTs. The core objective is to quantify influence of TAM and determine whether and how PM2 and AMP requirements enhance agency's internal programming processes and connects with TAM. The study will assess whether and how these initiatives have impacted capital or operating costs and identify gaps, challenges, and opportunities for further improvement.

The project is structured in two phases:

Phase 1: Performance Metrics and Data Evaluation.

Nationwide, assess the submitted AMP and TPM PM2 data and available literature/DOT websites to get the general picture of most DOTs' current practices. Based on this assessment recommend at least four State DOTsto evaluate performance metrics and data to establish a quantitative basis for measuring cost savings and other realized benefits.

Note: Proposers shall demonstrate that they have access to the data and systems they propose to use.

Phase 2: Comprehensive Assessment.

Building on the foundation created in Phase 1, at a minimum, conduct a comprehensive cost-benefit and impact assessment to provide actual data on the use of TAM, TPM, and TAMP

frameworks and whether and how TPM PM2 and AMP may have influenced asset management decision making.

Topic: HRDI-EPM-06

Title: Incorporating Nondestructive Evaluation Technologies into Pavement Asset Management

Nondestructive evaluation (NDE) technologies offer a powerful means of collecting timely, high-resolution pavement condition data across large areas, without causing any damage to the pavement structure. Figure 1 presents a conceptual example illustrating the benefits of integrating NDE into pavement asset management practices.

By providing more accurate assessments of pavement condition, NDE can help identify critical distresses that might otherwise go undetected using traditional methods. In the illustrated example, the yellow-shaded region reflects an overestimation of pavement condition in the absence of NDE, failing to capture actual deterioration shown in the red-shaded region. This oversight could result in unexpected failures or out-of-service pavement. Conversely, the use of NDE enables the detection of underlying issues, guiding proactive decision-making, as shown by the green solid line, and extending the service life of the pavement (represented by the green-shaded area).

In some cases, NDE may also reveal that pavement condition is better than assumed, preventing unnecessary repairs and avoiding wasted resources.

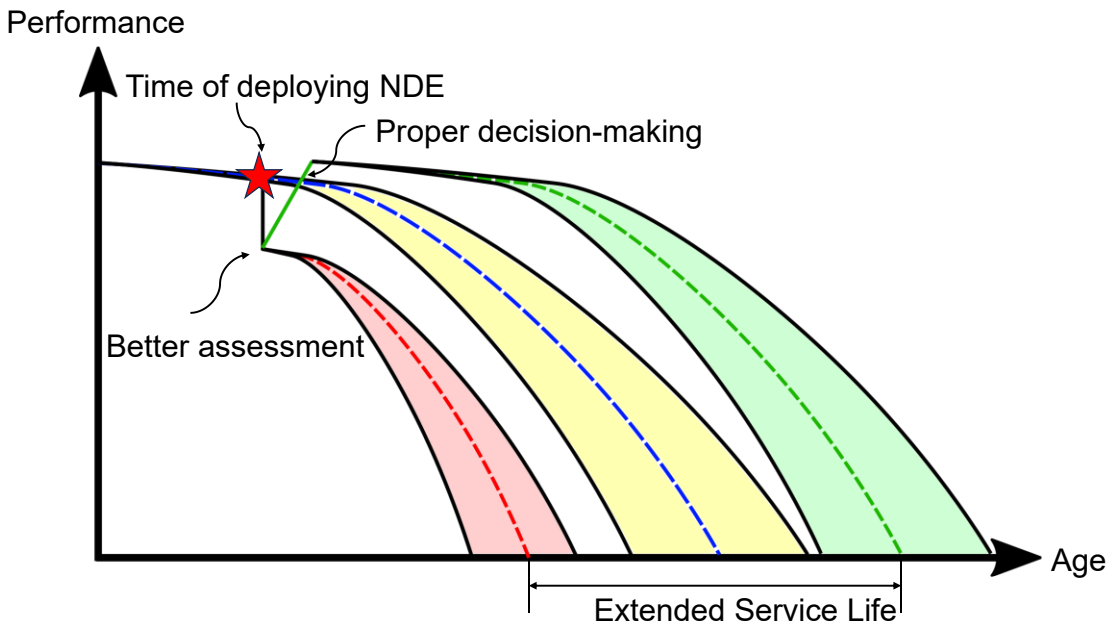

Figure 1. A mock-up example to illustrate the benefits of incorporating NDE into pavement asset management.

Despite its clear advantages, the implementation of NDE technologies across State DOTs remains inconsistent. While some agencies routinely apply NDE for pavement assessments, others use it infrequently or only on a case-by-case basis. Common barriers to broader adoption include:

1. A lack of quantitative evidence demonstrating the return on investment (ROI) for integrating NDE into asset management.
2. The absence of a practical, operational model showcasing how NDE can be successfully integrated with pavement management systems.

This research aims to address these challenges by:

- Identifying available NDE technologies that are currently deployed, or show strong potential, for use by State DOTs.
- Assessing the role and perceived value of NDE in supporting pavement asset management decision-making.

- Evaluating the ROI associated with NDE technologies in the context of pavement management.
- Developing a working model to demonstrate how NDE can be effectively integrated into a pavement asset management system.

Bridge Preservation and Management

Topic: HRDI-BPM-05

Title: Digital As-Built Data for Improved Bridge Management

Background: 3D bridge digitalization is an important step towards bridge digital twin creation and utilization. Digital twin is defined by the National Academy of Science as, "a set of virtual information constructs that mimics the structure, context, and behavior of a natural, engineered, or social system (or system-of-systems), is dynamically updated with data from its physical twin, has a predictive capability, and informs decisions that realize value. The bidirectional interaction between the virtual and the physical is central to the digital twin." (1,2) A digital twin of a bridge is composed of multiple components, which interact with each other and effect actionable decisions. Steps can be taken today to work toward digital twins and take advantage of increased data accessibility for information (include the 3D reference data) to enhance decision making. In the case of asset management developing digital workflows of data from design and construction provides opportunities to improve modeling, analysis, and decision making.

State DOTs and other bridge owners are advancing the concept of making the bridge model the legal document (no paper plans) for construction and concluding with digital as-builts that include associated contextual properties and metadata. This provides a foundation and makes it practical to explore the data needs to establish a digital twin for a bridge once construction is completed. It is a baseline and starting point, containing information for future operation, inspection, and management. For in-service bridges, the digital as built and referenced information originates during project delivery but it should be augmented with inspection and other relevant data post-construction. Any time something is done to a bridge, the data should be collected and integrated into the system of record to support asset management.

Bridge management can benefit from the expanded data that can be made available by using a digital lifecycle approach to managing data. Example data includes, but is not limited to, design and as-built data, construction quality data, bridge inventory data, condition assessment, preservation/maintenance history data, load rating evaluation data, weather data (macro and micro), natural or hazardous event occurrence, frequency, magnitude, and effect, operational data including load history and inspection/monitoring history, etc. Recording and tracking data with geospatial location and temporal specificity offered by 3D referencing will provide opportunities

for more effective data collection and for improved data representation, data types, models, analysis procedures, and use within bridge asset management.

This project will focus on assessing the benefits of 3D digitization and 3D referenced information, identifying the new, revised, or expanded datasets that would support the benefits, and developing a framework and strategic work plan for using bridge digitalization data for bridge management. ISO 19650 and IFC 4.3 accommodation and results from FHWA study "Advancing BIM for infrastructure: National Strategic Roadmap" and Transportation Pooled Fund TPF-5(523) – BIM for bridges and structures shall be considered.

Objective: The goals of this project are to assess and document the benefits that a lifecycle approach to digital workflows will provide to bridge management and develop a strategic work plan for achieving the advancements that would be required for these benefits.

Activities must include:

1. Document the data available and/or needed to develop an optimized digital as-built model which can represent the bridge at the start point for operation in support of bridge management.
2. Identify the information from design and construction that would enhance current bridge management processes. Also describe the format this data should be in and how the data would be transferred to bridge management. This effort should be consistent with openBIM™ approach of the work being carried out in TPF-5(523).
3. Identify how digital models and model referenced data can advance the achievement of bridge management objectives and enhance its functions.
4. Develop a potential framework and workflow from digital-as-built creation to management decision making (include multiple application functions) and what mechanism can be used to facilitate the information/data access.
5. Document data needs, source, collection, standardization, and management strategies for each step identified in the workflow. Consistency with ISO 19650, buildingSMART International's IFC 4.3 (ISO16739) accommodation, and results from TPF-5(372) and TPF-5(523) shall be considered in this project.
6. Identify the required interactions and enhancements to bridge asset management applications, including materials and quality assurance data, bridge management systems, and inspection data collection. Processes and maintenance management systems to provide, receive, and utilize digital models and model referenced information.

7. Develop a strategic roadmap for using currently available and proposed data/information in a digital twin framework that is ISO 19650 and IFC4.3 conforming with the purpose of enhancing bridge management.
8. With stakeholder input, provide recommendations for technology providers regarding direction, function, and features that will support bridge owner asset management needs. Among other technologies include inspection data collection applications, bridge management systems, and maintenance management systems.
9. Conduct and record an engaging and interactive national virtual workshop to present the project findings and deliverables.

Deliverables

1. A project final report.
2. Separate standalone documents "Digital As-Built Data for Improved Bridge Management" and "Strategic work plan to achieve the benefits of 3D digitization from operation to replacement")
3. A national virtual workshop that meets FHWA's Section 508 accessibility requirements and other approval requirements to post the recording for public access on FHWA's website.
4. Participate in monthly virtual meetings with FHWA staff to discuss project activities and progress.

References:

1. National Academies of Sciences, Engineering, and Medicine. "Foundational Research Gaps and Future Directions for Digital Twins." Accessed February 25, 2026. https://www.nationalacademies.org/projects/DEPS-BMSA-21-03/about.
2. National Academies of Sciences, Engineering, and Medicine. 2024. *Foundational Research Gaps and Future Directions for Digital Twins*. Washington, DC: The National Academies Press. https://doi.org/10.17226/26894

Pavement Modeling and Performance (PMP)

Topic: HRDI-PMP-02

Title: PEM Durability Test Thresholds and Design Adjustment

The need for performance testing has increased in recent years with the introduction of new materials and increase use of reclaimed and supplemental cementitious materials. The concrete PEM effort is focusing concrete pavement mixture design and structural design toward addressing the failure mechanisms to deliver durable concrete rather than just high strength concrete. It is important for state highway agencies (SHAs) and industry to recognize the need and desire to incorporate durability related design requirements and testing into specifications to help ensure longer pavement life. Durability tests that relate to performance can be used as a pass/fail screening test during mixture design and hold added value for performance analysis.

The ability to identify and quantify the performance and service life impact of the various PEM design and performance parameters is an identified gap in the national PEM effort. There is a need by practitioners utilizing these durability tests to understand how material selection and mixture design changes impact the test results and what options may be available to improve the mixture design to ensure long term pavement performance. Furthermore, many new and innovative products and service manufacturers make claims about the sustainability or "greenness" of their products and processes. It can be difficult for an owner, agency, consultant, contractor, or specifier to sort through these claims without an accurate, repeatable, and objective evaluation to assist their selection. Durability tests and performance parameters can be used to assess these new innovations in concrete mixture designs and alternative materials and help evaluate claimed environmental, sustainability, resiliency, and life cycle benefits. Stakeholder engagement has identified the desire for Agencies to quantify and demonstrate the added value and performance impact of incorporating and advancing durability tests and concepts. Industry has also expressed a desire to be able to demonstrate the benefits to their contractors to illustrate the improved performance of their final product resulting from these enhancements.

Recent developments in these durability tests provide highway agencies and the concrete paving community with a unique opportunity to use mechanistic based durability tests and analysis for concrete pavement performance comparison, mixture design, and pavement design to integrate these different phases of construction using similar test methods and principles.

There is a need by practitioners utilizing these durability tests to understand how they can be used, how their material selection and mixture design changes impact the test results, and what options may be available to improve their mixture design to ensure long term pavement performance and gain the associated sustainability, environmental, and resiliency benefits. Guidance in this area will help facilitate the use of these durability tests and provide potential actions when a combination of materials and mixture design selected are not sufficient to meet the specified durability test thresholds or intended performance. To make the most informed materials and design decisions with regard to sustainability, decision makers must employ a tool or tools that allow comparison of different materials and design choices.

Objectives of this research are to promote the deployment and use of innovative and best practices to enhance and improve the performance of the Nation's transportation system. The objective will be enabled by conducting research to support PEM analysis and information that enable practitioners to demonstrate and quantify the benefits of PEM design and durability testing to help advance PEM into implementation and ultimately improve pavement performance and extend pavement life. The objectives will be enabled by the development of durability testing information for the practitioner, durability testing thresholds, and mixture design adjustments to enhance the test procedures and practices. Mechanistic based PEM durability test procedures are part of an important innovation to concrete pavement characterization and mixture design, and associated sustainability, environmental, and resiliency benefits.

The goals of this research are to design, conduct, and provide recommendations relating to supplemental PEM durability performance testing to develop, validate, and refine performance testing thresholds using a combination of concrete mixture performance tests to establish and refine their performance/acceptance indices thresholds. PEM performance tests, calculating the indices, and comparing them to field performance will provide a validation of PEM performance

testing indices and thresholds; and result in the refinement of the index thresholds, mixture design acceptance criteria, and AASHTO test and materials standards. Furthermore, the goals will enable agencies in conducting regional and local validation of testing parameters to enhance their PEM durability performance testing procedures, indices, and thresholds prescribed.

- Collect, assess, document, and prioritize the PEM durability tests for development of indices and performance threshold which can be used for mixture design analysis and comparisons.
- Develop state of the knowledge & assessment report and provide recommendations, priority, and rational for which PEM durability tests are most amenable to further development of indices and thresholds for mixture design analysis and performance comparisons.
- Develop the durability indices, thresholds, requirements, analysis, improved AASHTO standards, and PEM design requirements. The work conducted by other agencies and pooled funds shall be considered to avoid duplication.
- Develop a guidance document on material selection and mixture design changes that can impact/influence the durability test results and associated trends with specified performance thresholds.
- Develop a guidance document on the use of the test parameters, indices, and thresholds to support mixture design efforts and improve durability.
- Develop information to support users and agencies on development and sensitivity analysis of the durability tests, design requirements, and specification limits.
- Develop improvements to current and proposed AASHTO concrete PEM durability test standards.
- Develop use cases for the concrete PEM durability tests.