# 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-01 | Case Studies with BIM/Digital Twin Return on Investment | TBA | |
| HRDI-ADC-02 | Research with Model and Operational Digital Twins | TBA | |
| HRDI-ADC-03 | Automated Vehicle Impacts and Interactions with Physical Infrastructure | TBA | |
| HRDI-ADC-04 | Using Automated Vehicle Operational Data with Digital Twins | TBA | |
| HRDI-ADC-05 | Maintenance Equipment Fleet Electrification Infrastructure | TBA | |
| HRDI-ADC-06 | Integrating Maintenance and Preservation Asset Management with Digital Twins | TBA | |
| HRDI-ADC-07 | Enhance Digital As-Builts with Materials Quality Assurance Data | October 30, 2023 | G |
| HRDI-ADC-08 | Advanced Data Analytics for Construction Contracting and Administration | October 30, 2023 | C |
| HRDI-ADC-09 | Leveraging Handheld "pocket" lidar for Digital Construction Inspection and As-Builts | October 30, 2023 | D |

| | | | |
|---|---|---|---|
| HRDI-ADC-10 | Digital Delivery Stakeholder Group | October 30, 2023 | B |
| HRDI-ADC-11 | Digital Infrastructure Enablers – Data Transformation and Governance Options | October 30, 2023 | H |

| **Transportation Resilience and Safety (TRS)** | | | |
|---|---|---|---|
| **Topic Number** | **Title** | **Closing Date for Concept Papers** | **See Note Below Table** |
| HRDI-TRS-01 | Dissemination of Available Knowledge on Pavement Resilience | October 30, 2023 | A |
| HRDI-TRS-02 | Impact of Environmental Factors on Pavement Infrastructure | TBA | |
| HRDI-TRS-03 | Long Term Friction Performance for Concrete Pavements | TBA | |
| HRDI-TRS-04 | Risk Assessment for Bridge Preservation/Management Decision Making and Resilience Enhancement | TBA | |

| **Enhanced Pavement Management (EPM)** | | | |
|---|---|---|---|
| **Topic Number** | **Title** | **Closing Date for Concept Papers** | **See Note Below Table** |
| HRDI-EPM-01 | Enhanced Pavement Data Collection and Performance Modeling to Incorporate Effect of Pavement-Vehicle Interaction as Part of Use Phase Life-Cycle Assessment - | October 30, 2023 | E |
| HRDI-EPM-02 | Life-Cycle Assessment to Inform the Pavement Treatment Selection Process | TBA | |
| HRDI-EPM-03 | Supplemental Performance Testing and BMD Threshold Validation Using Well Documented Field Projects | October 30, 2023 | F |

| Bridge Preservation and Management (BPM) | | | |
|---|---|---|---|
| **Topic Number** | **Title** | **Closing Date for Concept Papers** | **See Note Below Table** |
| HRDI-BPM-01 | Automated Data Collection and Automated Decision Making for Bridge Performance Evaluation and Preservation/Management Decision Making | TBA | |
| HRDI-BPM-02 | Bridge Preservation Technology Evaluation | TBA | |
| HRDI-BPM-03 | Bridge Preservation and Management Enhancement with Digital Twins | TBA | |
| HRDI-BPM-04 | A Holistic Approach: Integration of NDE with Bridge Preservation and Asset Management Practice | TBA | |

| Highway Construction Safety (HCS) | | | |
|---|---|---|---|
| **Topic Number** | **Title** | **Closing Date for Concept Papers** | **See Note Below Table** |
| HRDI-HCS-01 | Assess Priorities for Highway Construction Worker Fatigue and Distraction | October 30, 2023 | C |

| Pavement Modeling and Performance (PMP) | | | |
|---|---|---|---|
| **Topic Number** | **Title** | **Closing Date for Concept Papers** | **See Note Below Table** |
| HRDI20-PMP-01 | Electric Road System: Investigation of Inductive Charging Research Gaps and Implementation Challenges | October 30, 2023 | D |
| HRDI20-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: $150,000 - $200,000 per year

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

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

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

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

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

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

# Advanced Digital Construction

**Topic: HRDI-ADC-01**

**Title: Case Studies with BIM/Digital Twin Return on Investment (ROI)**

Transportation agencies (DOTs) are interested in the concepts of Building Information Management (BIM) for Infrastructure and Digital Twins, how they apply to capital and network-level projects, and if the cost of transforming their business processes is worth the investment. To-date, limited research has been completed that looks at the business case, or return on investment (ROI), of adopting BIM and Digital Twin processes into an agency's workflow. Further, the work that has been done has been limited to higher-value capital projects. This research topic seeks to address:

1. Identify and develop good case study subject projects that encompass a range of project values.
2. Tools to help DOTs ease into taking on BIM/Digital Twin projects.

3. Identify and develop a range of ROI tools and methodologies that are applicable to the value range of DOT highway projects.

**Topic: HRDI-ADC-02**

**Title: Research with Model and Operational Digital Twins**

The term Digital Twin encompasses many different forms and concepts, and can look very different from application to application, depending on the context and implementation. Some digital twins are entirely physical model-based, where limited or no operational information is managed in the business process. There are also digital twins that are only operational, such as public transit systems or traffic control networks. Research is needed to study the interaction of model-based and operational digital twins and look toward the goal of a transportation system integrating both physical and operational elements to have a true real world-representative digital twin.

**Topic: HRDI-ADC-03**

**Title: Automated Vehicle Impacts and Interactions with Physical Infrastructure**

As Automated Vehicle (AV) use is expected to increase and contribute to a significant percentage of highway use, it is imperative to understand the interaction between the vehicles and highway infrastructure. There are many unknowns associated with the deployment of SAE Automation Level 4 and 5 vehicles; being proactive as to their use from a highway design and maintenance perspective will serve to contribute to the readiness of DOTs for their use. This topic will address research needs that include:

- Optimum pavement marking design, maintenance, and reflectivity.
- Highway design that is conducive to both AV and non-AV use.
- Steps that may be taken now to be best positioned for future AV use.
- Impacts unique to AV deployment.

**Topic: HRDI-ADC-04**

**Title: Using Automated Vehicle Operational Data with Digital Twins**

Assistive (SAE Levels 1-3) and fully automated (SAE Levels 4-5) driving technology relies on a cadre of sensing and image processing equipment coupled with machine learning (ML) and artificial intelligence (AI) algorithms to accomplish automation tasks. Along with capturing situational data for the vehicle's own uses, such data could be beneficial to provide operational information in near real-time, feeding into a digital twin. This data might include traffic, infrastructure condition, and information about non-motorized modes such as bikes and pedestrians. This topic would explore such applications and look at the feasibility and applicability of AV information being used toward supplying information to digital twins.

**Topic: HRDI-ADC-05**

**Title: Maintenance Fleet Equipment Electrification Infrastructure**

As some states move toward mandating DOT vehicles and equipment be powered with energy sources other than gasoline and diesel, DOT equipment fleet operators are looking ahead to modify their existing servicing, fueling, and storage facilities to accommodate this paradigm shift. Battery electric vehicles (BEVs) will need sufficient charging infrastructure to keep them ready for the demands of heavy DOT use, and an accompanying technical staff well-trained in the maintenance and repair of electric vehicles. The Bipartisan Infrastructure Law (BIL) provides for an aggressive increase in the number of highway charging stations for the travelling public but is generally silent on the topic of DOT equipment and vehicle electrification infrastructure. FHWA has identified, via input from the national maintenance equipment fleet stakeholders, a need for research in this general area. Focus on this topic may include:

- Changes to DOT equipment fleet operational, storage, and maintenance facilities in an environment where the DOT will transition away from petroleum-powered vehicles to other power sources such as BEVs, hydrogen fuel cells, and hybrid technologies.
- Sourcing, training, and retaining qualified vehicle technicians that are well positioned to provide traditional in-house maintenance and repair of mixed-fleet, BEV, and other alternative-fueled vehicles.

**Topic: HRDI-ADC-06**

**Title: Integrating Maintenance and Preservation Asset Management with Digital Twins**

As DOTs move toward the adoption of lifecycle-based business processes such as BIM for Infrastructure/Digital Twins, it will be important to incorporate infrastructure maintenance and preservation activities into the overall process. Such activities generally fall within the operations and maintenance part of the lifecycle spectrum. Although some states and a few international cases have been successful in starting to accomplish this, there is still an overall need for research into how to best incorporate maintenance processes and the accompanying data into the lifecycle model or digital twin. This research topic aims to explore operations and maintenance/preservation activities and data into DOT lifecycle business processes.

**Topic: HRDI-ADC-07**

**Title: Enhance Digital As-Builts with Materials Quality Assurance Data and Develop Pavement and Materials BIM Data Schema**

Analysis, visualization, artificial intelligence, machine learning, and robust data analytics are increasingly being used across many industries to leverage electronic data assets, create workflows, and improve the efficiency of data utilization to make informed data driven decisions. In the highway construction field, there is increasing use and need for linking data sources together to leverage use in many different areas such as design models, intelligent construction, e-Ticketing, materials testing, digital as-builts, pavement management systems (PMS), and BIM for Infrastructure applications. Although materials testing and electronic data associated with quality assurance efforts have long been the basis of highway construction, it is the least mature in ability to analyze and leverage the results and data assets; and provide additional value beyond simply storing test results in hard copy inspection records or a database. Many agencies are interested in these technologies and want to maximize the use of their electronic data but are challenged by the associated analysis and integration. Agencies are trained to use the test equipment and produce quality data but are then left on their own to figure out how to analyze, interpret, leverage, and integrate the data into their workflows and other systems to maximize efficiency and use.

For example, results from a recently completed research study on Quality Assurance Data Analysis as a Leading Indicator for Infrastructure Condition Performance Management (FHWA-HRT-22-027) found that "traditional QA data elements are correlated to performance and show promise for use in PMS forecasting. Data from innovative QA test methods and construction technologies demonstrate direct or indirect correlation to performance. However, for use in PMS, agencies need to establish systematic procedures for data collection, storage, and access." There is an urgent need for robust systems that allow for agencies to integrate quality assurance and construction data as leading indicators of performance into their PMS.

At the same time, under Every Day Counts, round 6 (EDC6), FHWA is currently engaging with state agencies to develop digital as-builts that allow easier access to project level information from design and construction later in the life cycle. As part of these efforts, Materials QA has been identified as a missing link in digital project records and an area ripe for increased attention and increased data integration.

Many agency and contractor efforts have been made to develop various laboratory information management systems to store, analyze, and make use of their testing and QA data. Their experience is often less than ideal due to an excessive amount of handholding and the detailed construction and QA experience required in reviewing and guiding vendors and technology solution providers. There are many vendors that can provide systems to store data but do not have highway construction, testing, or QA expertise and experience to understand how the data is used; nor it's potential for future use. This experience is typical across the U.S. due to a lack of robust off the shelf systems available to address this integrated QA need domestically. Some contractors have sought solutions internationally due to the lack of robust domestically available solutions; or they have invested significant resources and funds in developing a custom solution.

Agencies are progressing toward BIM for Infrastructure as the successor to the standard plan set for highway infrastructure projects and are utilizing a variety of tools and equipment from multiple vendors and manufacturers to gather, display, and work with the data necessary for infrastructure project development, and interoperability of the models is a critical feature so that the agencies have the ability to transfer data seamlessly across BIM platforms. Data transfer necessitates a single data schema that is recognized as the industry standard, otherwise there is a

potential loss of data when translated from one device or one application to another; however, there has been a lack of consensus for adoption of pavement and materials data schema.

Goals of this research are to assess the beneficial uses for electronic QA data and gain knowledge to inform FHWA on its capabilities, limitations, and implications for use in advanced digital construction management systems and lifecycle asset management decisions and develop a materials QA data and pavement and materials data schema. It will result in an awareness of stakeholder QA data analytics and integration needs that are required to leverage QA data assets, integrate QA test data into advanced digital construction management systems and use for digital as-builts, and BIM for Infrastructure, and associated technology gaps.

Efforts may lead to follow on activities based on findings and technologies; including commercial interest to provide robust solutions and fill in the identified gaps to current systems and technologies. The successful completion of this project will provide a strong foundation and data driven approach for specific follow up activities and initiatives for emphasis, development, and deployment of advanced digital construction management systems.

Assess the current state of knowledge and practice of electronic QA data use, potential, and integration; its capabilities, limitations, and implications for use in advanced digital construction management systems and lifecycle asset management decisions. Assess the prevalence of geospatial location information and current available QA data schemas and standards. Investigate, assess, document, and prioritize electronic QA data and gain knowledge thru:

1. A comprehensive review to collect, assess, and document current state of practice and future potential uses.
2. Develop state of the knowledge & assessment report and provide recommendations, priority, and rational for which electronic QA data needs or gaps are most urgent to enable widespread adoption and use for digital as-builts and BIM for Infrastructure.
3. Assess the beneficial uses for electronic QA data and gain knowledge to inform FHWA on its capabilities, limitations, and implications for use in advanced digital construction management systems and lifecycle asset management decisions. Research of interest include but not limited to:

- Assess and document uses for electronic QA data based on stakeholder interests and potential future opportunities.
- Assess and document their data storage, data analytics, and data integration needs to leverage their QA data assets to support broader agency business objectives.
- Assess availability of off the shelf systems, and document their analytics, robustness, and integration abilities (including commercial systems and AASHTOWare systems).
- Assess their capabilities and limitations.
- Assess and document pros and cons.
- Assess and document use for digital as-built data collection and BIM for Infrastructure initiatives.
- Assess and document gaps in available systems based on stakeholder needs.
- Assess and document recommended analytics, data visualization, and integration strategies for electronic QA data.
- Assess and document data standards that exist, are required, or needed.
- Assess and document enabling technologies and systems required.
- Assess and document complimentary technologies and systems which enhance use, functionality, or accuracy.
- Assess the prevalence of geospatial location information of QA and pavement and materials data.
- Assess current available materials QA and pavement and materials data schemas and standards.
- Building on the assessment, develop a materials QA data and pavement and materials data schema that is open source and in alignment with existing BIM for Infrastructure and ISO efforts and standards. The data schema must be in compliance with ISO 19650,

**Topic: HRDI-ADC-08**

**Title: Advanced Data Analytics for Construction Contracting and Administration**

Data science, data analytics, artificial intelligence (AI), and machine learning (ML) have been proven valuable in supporting project bundling decisions by Indiana DOT to maximize cost

saving and significantly reduce the time it takes to create bundles from a week to minutes. INDOT's use of data analytics for transportation project bundling is the first of its kind, but it's highly replicable.

Transportation engineers typically group infrastructure construction projects into bundles to gain efficiencies in contracting and project management, minimize infrastructure disruption and achieve economies of scale. Bundles are created from similar projects – bridge projects, freeway lighting installations or safety improvements – or from a variety of types of work in a specific location. Bundling is complex, manual, subjective process, with engineers usually working from maps and spreadsheets.

INDOT has done manual project bundling for about five years and used that data to test benefits of data analytics enabled bundling, in which an algorithm that had been trained on historic data makes bundling suggestions. Using the technology has increased savings from bundling by 40% and could save INDOT $108 million in the next four years. But the real advantage is speed; instead of having to sit down and create maps and drawing everything by hand, data analytics speeds the process.

AI and ML can quickly evaluate large volumes of data to identify and combine project to provide a better return on investment for Indiana DOT. There are other large construction and contract related data sets that could benefit from more advanced data analytics. For example: project estimates, bid reviews and unbalanced bids, change order analysis, claim evaluations, and impacts of bid and market competition.

Goals of this research are to assess the current state of knowledge and state of practice for using artificial intelligence, machine learning, and advanced data analytics; and it's potential to bring solutions to highway construction contracting and management business practices and decision making. This assessment will result in an awareness of stakeholder data analytics and integration needs that are required to leverage existing data assets and bring efficiencies, time and cost savings, and improvements to highway construction contracting and administration business practices and workflows. The result would provide a guide for State agencies to enhance their analytic capabilities and support targeted pilot projects.

Efforts may lead to follow on activities based on findings and technologies; including commercial interest to provide robust solutions and fill in the identified gaps to current systems and technologies. The successful completion of this project will provide a strong foundation and data driven approach for specific follow up activities and initiatives for FHWA emphasis, development, and deployment of data analytics for construction contracting and administration.

Assess the current state of knowledge and practice of data analytics for construction contracting and administration. Review, investigate, assess, and document data analytics for construction contracting and administration and gain knowledge thru:

1. A comprehensive review to collect, assess, and document current state of practice and future potential uses.
2. Develop state of the knowledge & assessment report and provide recommendations, priority, and rational for which data analytics needs or gaps are most urgent to enable widespread adoption and use in construction contracting and administration.
3. Assess the beneficial uses for data analytics for construction contracting and administration and gain knowledge to inform FHWA on its capabilities, limitations, and implications for use in agency business practices and workflows. Research of interest include but not limited to:
    - Assess and document uses for data analytics for construction contracting and administration based on stakeholder interests and potential future opportunities.
    - Assess and document their data storage, data analytics, and data integration needs to leverage their data assets to support broader agency business objectives.
    - Assess availability of off the shelf systems, and document their analytics, robustness, and integration abilities.
    - Assess their capabilities and limitations.
    - Assess and document pros and cons.
    - Assess and document data analytics use for construction contracting and administration initiatives.
    - Assess and document gaps in available systems based on stakeholder needs.

- Assess and document recommended analytics, data visualization, and integration strategies.
- Assess and document data standards that exist, are required, or needed.
- Assess and document enabling technologies and systems required.
- Assess and document complimentary technologies and systems which enhance use, functionality, or accuracy.

4. Provide direct support and subject matter expertise related to efforts on data analytics for construction contracting and administration.

**Topic: HRDI-ADC-09**

**Title: Leveraging Handheld "pocket" lidar for Digital Construction Inspection and As-Builts**

Investigate applicability and limitations of new handheld consumer pocket lidar technologies for field use in construction inspection and developing digital as-builts. FHWA awarded a research contract for Phase 1 to evaluate Apple Inc's pocket lidar sensor capabilities and accuracy in Sept 2021. Results to date are promising as testing and evaluation of the sensor included in both iPad Pro and iPhone 13 Pro have indicated capabilities to scan and document point cloud data for highway construction projects.

One dependency of data accuracy collected is which application (app) is utilized for scanning and capturing the point cloud data. Current budget limited the number of apps that can be assessed as part of the Phase 1 efforts; and construction inspection focused apps have just recently emerged that are utilizing the pocket lidar sensor data. Another dependency is tied to the camera sensor quality and associated photogrammetry data generated by the cameras.

The project has significant interest by the community. The efforts were highlighted in FHWA's Innovation in Project Delivery May e-News and resulting in several inquiries from readers and State agencies and how they can get involved with any case study efforts or technology deployment. The AASHTO COC specifically requested a presentation on the technology and research efforts at their 2022 annual meeting in August.

A Phase 2 project will expand on the current project and will provide resources to further leverage the technology and assist construction inspectors via the below listed activities:

- Identify and evaluate additional apps and their ability to accurately capture point cloud and photogrammetry data of highway construction project assets.
- Evaluate improved camera and pocket lidar sensors in the next version of consumer grade electronics released by Apple Inc.
- Investigate the ability to integrate the pocket lidar data with augmented reality, and reality capture via Apple's AR-KIT to further supplement highway construction inspector duties and assist visualization of project features and design models.
- Investigate the ability to leverage Apple's new RoomPlan to enable Scan-to-BIM of as constructed or installed features.
- Identify, exhibit, and document additional use cases with State agency and Federal Lands Highway Divisions

**Topic: HRDI-ADC-10**

**Title: Digital Delivery Stakeholder Group**

Digital technology has brought about the ability to integrate and manage an agency's enterprise data throughout an asset's lifecycle, as well as for operations (e.g. structural health and ITS/connected vehicles). This transformation within the highway community towards leveraging agency-wide data has gained great momentum and there are a number of strategic efforts underway that should be coordinated to ensure they are complementary and not duplicative. For example:

- FHWA has been actively advancing awareness and resources to help bring about this digital transformation via its Every Day Counts and other BIM (Building Information Models, or more aptly, Better Information Management) efforts, including multiple pooled fund projects with 20+ State participants.

- The new Advanced Digital Construction Management Systems (ADCMS) program in BIL will significantly fund promising agency projects that are expected to move the digital transformation needle for the infrastructure industry.
- Concurrently, AASHTO has established joint committees and become members of buildingSMART International in order assist the State DOTs in moving towards better data integration.
- The FHWA Planning Office is also working on GIS initiatives that support lifecycle asset management, as well as reporting to FHWA (e.g. HPMS, NBIS, MIRE).
- The FHWA Operations office is working on a digital infrastructure initiative that is expected to advance the next wave of intelligent transportation systems and connected vehicle operations support.
- NCHRP has a number of research projects underway to fill gaps related to U.S. BIM for infrastructure implementation.
- Looking beyond infrastructure, the National Institute on Building Sciences (NIBS) has developed a national strategic plan for BIM that encompasses both the vertical and horizonal construction industry.

With all this and other activities ongoing, there is a need to ensure efforts are coordinated and that various parties are aware of what all these groups are doing. This helps to avoid the duplication of effort and allows for individual efforts to be optimally leveraged for the greater good of the highway community. FHWA is in a unique position to provide national leadership and resources to facilitate a more concerted and productive effort to realize the benefits of digital delivery, much as we are seeing national transportation agencies do in other leading countries (e.g. Netherlands, Norway, Denmark, UK, Korea, China)

The objective of this task is to assist the FHWA in the preparation, execution, and documentation of the Digital Delivery Stakeholder Group (DDSG) meetings. These meetings will be a mix of in person hybrid meetings and virtual via conference call or video conference, or other means. It is expected that the DDSG will have 1 to 2 in person meetings a year and 1 to 3 virtual meetings per year. The Contractor shall be responsible for all tasks associated with the meetings including but not limited to scheduling, arranging for meeting facilities or virtual platform, invitational travel for State DOT, Local Public Agency, and Academic members, taking notes and providing

minutes. All activities related to the DDSG meetings shall be coordinated with the task manager. It is expected that two contract staff employees will participate in the DDSG meetings. The Contractor shall notify and obtain FHWA approval if additional contract personnel are required to meet the needs of the program.

*Results/Action oriented Agenda*

A formal agenda shall be established for each meeting with input from the task manager and anyone deemed necessary. The agenda should be designed for getting to results; having the right people attend that can make critical decisions and develop/execute follow-up actions (i.e. meeting should aim for specific action items and communications that advance the coordination of various digital delivery initiatives). The task manager is required to obtain formal approvals from the FHWA CFO's office for each in person meeting. These approvals may take up to 90 to 120 days to complete and the Contractor shall plan accordingly. Site visits may be included in the meeting agenda. The Contractor shall help facilitate the meetings. Notes, recordings and minutes of the meeting will be provided by the Contractor.

*Retain Meeting Facility*

The Contractor shall be responsible for all activities associated with retaining a facility for each DDSG meeting. Up to two in person meetings per year are anticipated in this task order. Each meeting is estimated to last up to two days.

The meeting location and facility shall meet the following criteria:

- Preference for the meeting room shall be in a government owned facility (Federal, State or Local) when available and cost effective.
- Hotel rooms shall be available for members and reserved as a block at Government per diem rate (see GSA Schedule at https://www.gsa.gov/travel/plan-book/per-diem-rates)
- The meeting location shall have a meeting room that can comfortably accommodate all meeting participants and allows for virtual participation. For planning purposes, the meeting room must be designed to hold at least 35 persons.

- Room arrangements shall include all associated costs, as well as projection screen, digital projector, laptop, appropriate microphone and audio capabilities, flip chart, and connections for Internet and Telephone.
- For virtual meetings, the contractor is responsible to identify the meeting platform that supports the meeting needs. The virtual meeting platform shall meet the following criteria:
- Video capability for participants and at a minimum for speakers
- Breakout capability
- Chat capability with participants and meeting hosts
- Host as many as 300 participants
- Recording ability (including 508 compliance and the ability to post recordings on FHWA's website)
- Screenshare

*Notification and Meeting Arrangements*

The Contractor shall work with FHWA but will ultimately be responsible for all tasks associated with notifying DDSG participants of meetings logistics and other pertinent information relevant to the meeting. All meeting information shall be prepared by the Contractor, approved by FHWA, and distributed in a timely fashion as directed by the task manager. Meeting announcements will need to clear FHWA's editorial and Public Affairs review and approval processes which take at least 6 weeks. The in person hybrid meetings will also require FHWA conference approval which can take up to 90 days. Material distributed by the Contractor shall include confirmation letters, emails with meeting details, meeting agendas, and other meeting information. Meeting location details and invitational travel notification letters to participants shall be distributed not less than 60 days prior to the meeting date.

*Travel Arrangements (In person hybrid meetings only)*

The Contractor shall develop appropriate invitational travel reimbursement forms, make travel arrangements, and is responsible for reimbursing appropriate travel-related costs for DDSG members employed by State DOTs, Local Public agencies (i.e., municipalities) and academic

institutions. For estimation purposes, assumes that reimbursement will be made for 15 people per meeting using GSA Per Diem rates and contract airfares. The cost per person attending each meeting is estimated to be approximately $1500. In addition to members whose travel is covered by FHWA, it is anticipated that the DDSG will also include members from industry, NIBS, bSI, AGC, ARTBA, TRB and others. Copies of all correspondence with DDSG participants shall be provided to FHWA. Reimbursements for travel will be considered as direct costs.

*Facilitate/Conduct Meetings/Teambuilding*

The Contractor shall be responsible for all coordination activities associated with the meetings. The Contractor's personnel shall assist the FHWA to actively facilitate the meetings towards results and follow-up actions. The contractor shall provide activities that serve to build a strong coalition and team among the various stakeholders towards accomplishing the key objectives collaboratively. Activities associated with this task include but are not limited to designing effective polls, facilitation and team-building activities, coordination with local facility personnel, recording information and preparing minutes of meeting discussions. The Contractor shall provide copies of the agenda, all presentation material, and handouts associated with the meetings and distribute them to members and meeting friends, preferable at least 5 business days prior to the meetings. Contractor shall begin each subsequent meeting with a report and check in on the status of outstanding action items.

*Site Visits (In person meetings only, Optional)*

It is possible that site visits may be conducted as part of the DDSG meetings. Site visits are intended to be informative and provide DDSG members and friends with pertinent information related to ongoing ADCMS projects. The Government may exercise this option to include a site visit for all DDSG participants during any of the in-person meetings. The Contractor is responsible for coordination of site visits with the FHWA and for all necessary transportation and other arrangements. Minutes for these site visits will not be required. Costs for site visits (e.g., transportation) will be considered as direct costs.

*Post Meeting Activities*

Meeting minutes documenting the meeting discussion and outcomes shall be submitted to the FHWA within 10 calendar days after the meeting for review and approval. FHWA will return comments within two weeks of receipt of the minutes. The minutes, in addition to other pertinent information from the meeting, shall be distributed by the Contractor to the DDSG members and friends within 5 calendar days from receipt of the approved minutes from the Task Manager.

Deliverables: Confirmation letters to participants 60 days prior to meeting, travel arrangements completed for DDSG members 10 days prior to meeting, reimbursements to travelers within 30 days after the meeting, 1 Copy of draft minutes to Task Manager 10 days after DDSG meeting, electronic copy of final minutes to all DDSG participants 5 days after receipt of FHWA approval.

**Topic: HRDI-ADC-11**

**Title: Digital Infrastructure Enablers – Data Transformation and Governance Options**

Digital technology has brought about the ability to integrate agency enterprise data and has been the focus of FHWA's BIM (Better Information Management) efforts. This effort aims to investigate developments in edge computing and assess the feasibility of applying the real-time data analysis it enables to the broader goal of Digital Infrastructure. It will also work with stakeholders to extend the Data Governance Framework that FHWA has developed for BIM to Digital Infrastructure. Project results will allow FHWA to address and promote optimal approaches for leveraging and managing data from disparate systems and help our transportation partners better understand edge computing within an objective highway agency context.

This topic is a result of the identification of key enablers at the March 2023 Digital Infrastructure Strategic Focus workshop. The resulting project will be closely coordinated with Operations and Safety, as these are the areas with the greatest need for real-time decision making. Discussions were held with HOP and HRSO staff who also participated in the workshop to develop this proposal. It is anticipated that these will be 12-month efforts and outreach will occur during and after the project.

This project has two components:

1. Assess the applicability of edge computing to better enable Digital Infrastructure

   Current data analysis approaches are primarily focused on sending data to cloud applications, conducting data analyses there and then transmitting results back for decision making. Edge technology presents an opportunity to establish a common data environment at a midpoint between individual sensors or data collection efforts and the cloud. This could allow for more efficient transfer and integration of data, especially for data where the real-time element is paramount. Edge computing supports real-time processing for near real time decision-making, avoiding the latency in sending large amount of data to cloud for processing. At the same time integration of data from distributed sources is needed on an as needed basis. This effort explores the feasibility of integrating edge computing that process large amount of sensor or real-time data at the source and serve it as data source for as needed data integration. This "near source" data transformation represents a paradigm shift in how data is managed and stored.

2. Applying BIM Data Governance Framework to Digital Infrastructure

   Digital Infrastructure, and its related disciplines (digital twins, BIM for Infrastructure, Digital As-Builts, etc.), utilize very large amounts of data that are pulled from many disparate sources and systems. In order to work efficiently, their data flows must be governed by a set of rules, or structure, so that the information is readily useable and in a form that all systems understand. At present, such a structure does not exist; rather, systems within the digital world of infrastructure rely on a range of often incompatible data structures and formats that may not always be efficiently translatable to each other. Of the many workshops and forums held with digital infrastructure stakeholders, along with FHWA research findings, a nearly universal need and request is the development of a data structure and governance framework that may be adapted by DOTs to form the basis for the particulars of their enterprise, while also adhering to a national, or even international, consistency.

This effort extends and leverages the Data Governance and Structure research work that was recently completed for BIM for Infrastructure, extending its scope to the larger field of Digital Infrastructure. Since BIM for Infrastructure is essentially a specific discipline under the broader

field of Digital Infrastructure, it is anticipated that the governance and structure developed for BIM will apply well to digital infrastructure. This effort would necessarily be collaborative with national stakeholder outreach, and be discipline-crosscutting by nature, especially with infrastructure, operations, information technology, and others.

# Transportation Resilience and Safety

Resilience is becoming an increasing critical consideration for highway and transportation engineers. It is time to incorporate resilience into the transportation design, management, and decision-making processes. A recent report summarizing feedback from state agency design engineers and industry stakeholders on pavement design identified resiliency as a factor to be incorporated into the design process (FHWA Summary Report).

According to FHWA Order 5520, resilience is the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions. As noted in that order, climate change and extreme weather events present significant and growing risks to the safety, reliability, effectiveness, and sustainability of the Nation's transportation infrastructure.

**Topic: HRDI-TRS-01**

**Title: Dissemination of Available Knowledge on Pavement Resilience**

Pavement resilience is an urgent issue. Many States are looking for resources to address problems such as flooding or pavement blowups while others have expressed interest in resilience (e.g., Maryland, Delaware, Iowa, Texas, Florida, etc.). This project goal is to disseminate available information on pavement resilience and describe the state of knowledge, practice, and future needs based on (1) key national and international climate documents, (2) a FHWA approach to resilience based on the Vulnerability Assessment and Adaptation Framework, (3) the results of a FHWA pavement resilience guidebook, (4) the findings from two FHWA-sponsored Peer Exchanges on pavement resilience held in late 2020, and (5) FHWA TEACR projects and other case studies.

Outcomes will be to provide a better understanding of the current definitions of resilience and vulnerabilities as it relates to pavements, identify strategies to incorporate resilience into pavement design, management, maintenance, and asset management, and highlight current state of practice, knowledge gaps and research needs.

The goal/purpose of this activity is to identify innovative approaches to incorporate resilience into pavement design procedures, management, and asset management for our stakeholders. The deliverables for this activity are webinars and workshops highlighting a comprehensive assessment of relevant climate stressors, hazards, and impacts for pavement assets, as well as recommendations for adaptation and engineering design at the project-level.

**Topic: HRDI-TRS-02**

**Title: Impact of Environmental Factors on Pavement Infrastructure**

This study offers the use of historical LTPP data (SPS-8 sections) and National Park Services' PMS database (i.e., EFL manages the PMS for NPS) to develop a series of deterioration models for different family groups of pavements to select the appropriate time-based preservation/rehabilitation strategies for pavement sections in the absence of heavy loads. These sections will be evaluated to assess the impact of climate change and matched with test sections from other LTPP experiments that have normal truck traffic to compare and show the proportion of total damage caused by environmental effects.

The materials used for construction, however, are often selected on the assumption of a stationary climate. Anthropogenic climate change may therefore result in rapid infrastructure failure and, consequently, increased maintenance costs, particularly for paved roads where temperature and precipitation are key determinants for material selection. Failing to update engineering standards of practice in light of climate change therefore significantly threatens pavement infrastructure in the United States. For the purpose of this study, different pavement family groups will be identified in different climate zones, and comprehensive evaluation of existing pavements will be conducted through analysis of different datasets.

Performance measures will be used to create the deterioration curves for each group of pavement family to fully characterize the condition of existing pavements, and damage factor determined from FWD data will be suggested as trigger factor to select rehabilitation candidates. Different levels of rehabilitation/preservation activities will be considered as potential alternatives for rehabilitation candidates. The deterioration curves will be employed to assess the impact of climate and obtain an estimate of environmental-induced damage as well as the performance of rehabilitation treatment and so extension in service lives of pavements. Also, an assessment output matrix will be developed, which can be served as a supplemental tool to help the decision-makers in the highway agencies with the climate related decision-making process.

This project will provide states with information related to the impact of climate change on pavement performance to improve planning for future renewal solutions.

**Topic: HRDI-TRS-03**

**Title: Long Term Friction Performance for Concrete Pavements**

Portland cement concrete production is around 200 million tons per annum into road pavements. The microtexture and macrotexture of concrete pavement surfaces are largely controlled by the type of texturing used. There needs to be research done on how grinding procedures, aggregate quality, truck traffic impacts, concrete strength, and some other factors affect long-term friction performance. The impacts of Portland Cement Concrete mixture design materials and specifications, grooving and grinding processes, and truck traffic on friction values needs to be evaluated and documented.

This research will document the effects of Portland Cement Concrete mixture design materials and parameters, grooving and grinding methods, and truck traffic on friction values. Data from the LTPP Program database as well as DOT's pavement friction management database could be used to establish the long-term friction performance for concrete pavements. This project is focused on both existing concrete pavements and new construction. This study aims to establish the friction performance of various materials and mix designs using different surface texturing techniques under various conditions (traffic load, climate, etc.).

This project will enhance the understanding of major factors impacting friction values and develop a friction toolbox to progress toward long-term friction performance for concrete pavements. Also, the objective is to establish a selection protocol for concrete pavement materials and texturing methods to provide suitable and sustainable friction performance.

**Topic: HRDI-TRS-04**

**Title: Risk Assessment for Bridge Preservation/Management Decision Making and Resilience Enhancement**

Risk based bridge preservation/management decision making is needed for both action prioritization practice and after event repair/rebuild. Data requirements, methodologies, models, and tools are needed for bridge risk assessment and management. Research is needed to evaluate the risk caused by bridge deterioration, climate change, extreme events, etc. Certain level of validation, which may include inventory data analysis, lab testing, and field testing, is important for result acceptance.

Once a risk assessment/management tool is developed, it can be used to optimize decision making and recognize cost-effective actions to avoid damage or repair damage quickly.

# Enhanced Pavement Management

Pavement management is a strategic approach to the optimal allocation of resources for the maintenance, preservation and upgrading of the pavement network. Pavement monitoring and data collection are an essential component of pavement management. Traditionally pavement management combined engineering and economic principles with sound business practices to support decision making at the strategic, network, and project levels. Consequently, current pavement monitoring and data collection and performance models developed were primarily focused on those two considerations – engineering and economic. In addition, the pavement management prioritizes treatment selection process based on engineering and economic considerations. However, with the increased awareness of the effect of climate change and the impact of the choices we make today on the society at present and future, a more encompassing consideration is the concept of sustainability that brings in the need to consider environmental

and social consequences, in addition to engineering and economics, of our decisions. Pavement management data can also provide valuable information for improving pavement design, material selection, and optimization techniques for achieving construction quality, all of which contribute to improved sustainability. Data collection is a continuous process, starting with documentation of pavement construction and continuing throughout the pavement life. Information that should be collected and stored over the pavement lifecycle needs to be reimagined to support the engineering, economic, environmental, and social aspects and will include data that are currently collected and new data items. In addition, network level pavement monitoring produces large amount of raw data, and this raw data is often converted to specific index or metric that are relevant to current decision making for ease of analysis and storage and performance models developed for those indices to support forward looking analyses. Additional such indices and performance models may be needed to support the incorporation of environmental and social considerations.

**Topic: HRDI-EPM-01**

**Title: Enhanced Pavement Data Collection and Performance Modeling to Incorporate Effect of Pavement-Vehicle Interaction as Part of Use Phase Life-Cycle Assessment**

Pavement vehicle interaction (PVI) describes the effect of pavement condition on vehicle fuel consumption (VFC) and vehicle operating cost (VOC). PVI focuses on how pavement condition, both functional and structural, impacts VOC and VFC, induced by rolling resistance from pavement surface texture, roughness, and pavement structural responsiveness or deflection and deformation. It is part of the use-phase of pavement lifecycle and an important component of the overall pavement Life-Cycle Assessment (LCA). Although the impact of PVI is small for a single vehicle travelling typical highway pavements in the United States, the cumulative impact over the life cycle for high traffic volume roadways can be a significant component of the life cycle footprint of pavements.

There is a long history and understanding on how pavement roughness impacts vehicle fuel economy, however, that is not the case for deflection, texture, and other rolling resistance factors. Even in the case of how pavement roughness impacts vehicle fuel economy, the models are largely based on empirical studies and often uses International Roughness Index (IRI) as the

predictor, an index developed to assess the ride quality of pavement. While IRI has been a good indicator of passenger comfort, it has limitations as a predictor of how pavement roughness impacts vehicle fuel economy of various vehicle classes. These gaps have spurred several research efforts in the last several years to better understand PVI and develop new or enhance existing models to assess the impact of pavement condition on EFC over the lifecycle. A recent FHWA's research effort reviewed and assessed the availability of and gaps in PVI related excess energy consumption (EEC) or fuel consumption (EFC) models and their compatibility and applicability within the context of pavement investment decision making under different use cases. This effort showed that existing models have the potential for use in assessing PVI related EFC as part of use-phase LCA, but a significant gap is the lack of some of the pavement condition data and performance models for predicting such over time.

This topic will address research needs which include:

1) Assessment of current and predicted pavement data requirement for the effective and responsible use of various available PVI-related EFC models as part of use-phase LCA.
2) Identify data that are currently collected or could be collected with current technologies and those that may require surrogate data or other innovative approaches.
3) Conceptual development of performance models for such data items to support LCA.
4) A framework/guidance for incorporating the new or enhance data items and performance models within pavement management systems.

**Topic: HRDI-EPM-02**

**Title: Life-Cycle Assessment to Inform the Pavement Treatment Selection Process**

Pavement management systems (PMS) use decision trees or other procedures to prioritize treatment locations, timings, and types to maintain a pavement network given funding constraints. With the establishment of life cycle planning (LCP) requirement in 23 CFR 515.7 (b) that defines life cycle planning as 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, there is steps towards considering lifecycle perspective in prioritizing treatment locations, timings, and types that is focused on engineer and economics. However, there exists an opportunity and need to additionally consider environmental impacts as part of

this selection process. This topic will address research needs that include how environmental considerations can be incorporated into the pavement management treatment selection process, data needs and collection opportunities, and LCA based metrics that can support such consideration.

**Topic: HRDI-EPM-03**

**Title: Supplemental Performance Testing and BMD Threshold Validation Using Well Documented Field Projects**

Rutting and cracking are two primary pavement distresses that affect asphalt pavement performance and service life. There are several performance tests standardized by AASHTO for evaluating both distresses to balance the two distresses during mixture design. These test parameters can be used by DOTs and industry to evaluate mixture performance within a Balanced Mixture Design (BMD) system.

Performance tests of note, include Hamburg Wheel Track Test, Stress Sweep Rutting (SSR) Test, IDEAL Cracking Test, Illinois Flexibility Index Test (IFIT) using Disc Shaped Compact Tension (DCT), Texas Overlay Test, Bending Beam Fatigue Test, and Cyclic Fatigue Test.

FHWA has developed BMD testing parameters and thresholds to assess asphalt pavement rutting and cracking during mixture design. The mixture design parameters use the stress sweep rutting (SSR) test (AASHTO TP 134) and the cyclic fatigue test (AASHTO TP 133). The SSR and fatigue tests can be used in the mixture design phase to assess rutting via the rutting strain index (RSI) parameter and cracking via the apparent damage capacity (Sapp) parameter. https://highways.dot.gov/research/infrastructure/pavements/flexmat. The parameter thresholds were developed utilizing a range of mixtures and traffic levels from projects located around the world including NCAT and FHWA ALF accelerated load test sites and in-service pavements from State DOTs.

Additional validation of performance test parameters and thresholds from pavements with well documented field performance provide an independent validation of the existing thresholds and provide data for further refinement of mixture design requirements and criteria.

There are existing and previous national level efforts such as NCHRP 9-49 and LTPP SPS-10 warm mix asphalt projects that have well documented long term pavement performance and distresses over time, extensive volumetric and surrogate performance test data, and have retained original materials from their in-service field projects. These project's documented performance and retained materials can be further leveraged for validation of BMD test thresholds by conducting and collecting the performance test data and information to validate existing thresholds and guidance.

In addition, State DOTs have cited the need to obtain estimates of variability of BMD tests under real-world production conditions for them to consider implementation of performance testing beyond just mixture design. A very large extensive effort would be needed to establish each individual BMD test's overall variability and is beyond the scope of this research. Furthermore, there are several sources of variability inherent in production of asphalt mixtures that can affect performance testing and the scope and scale of the impacts of these variabilities are largely unknown for BMD tests under consideration for implementation. However, conducting and documenting a literature search on BMD performance tests variability and identify test protocols areas of variability for each test may be considered. This could provide benefit to State DOT to better understand their performance testing variability and assisting the States in advancing performance testing more responsibly.

The goals of this research are to design, conduct, and provide recommendations relating to supplemental performance testing to validate and refine performance testing thresholds using a combination of asphalt mixture performance tester (AMPT) and non-AMPT mixture performance tests to establish and refine their performance/acceptance indices thresholds via projects with well documented long term field performance from national and local performance data. Conducting supplemental performance tests, calculating the indices, and comparing them to field performance will provide a validation of BMD 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 objective will enable agencies in conducting regional and local validation of testing parameters to enhance their BMD procedures, indices, and thresholds prescribed.

This research is targeted at State DOT projects with well documented field performance within the NCHRP 9-49 and SPS-10 field sites located across the U.S.; and can be supplemented with further identification of local sites from State or local public agencies and possibly expanded as funding becomes available.

The research may also consider conducting and documenting a literature search on BMD performance tests variability and identify test protocols areas of variability for each test; and provide estimates of typical production variability of the selected tests through the testing of mixtures from the targeted field sites.

# Bridge Preservation and Management

**Topic: HRDI-BPM-01**

**Title: Automated Data Collection and Automated Decision Making for Bridge Performance Evaluation and Preservation/Management Decision Making**

Although not yet ready for current operational practice, automated data collection and decision making represent the future operation for bridge evaluation, preservation, and management. The fast development in sensing and energy harvesting technologies, data analysis algorithms, data storage, computational, and communication capacity makes this more and more realistic.

Identifying data requirements and recognizing appropriate sensing and energy harvesting technologies for bridge applications are essential for automated data collection. Improving and optimizing data storage (in digital twin framework), analysis (AI-based edging computing approaches), and communication strategy can facilitate automated decision making and effective information dissemination.

Some existing Structural Monitoring (SM) systems already demonstrate basic applications for automated data collection and decision making. For examples, bridge fire, flooding, wind, and collision monitoring systems have allowed near-real-time actionable messages to be sent to related personnel for implementation. Recognize and demonstrate successful SM application cases will encourage a wider adoption of the technology and build momentum for future research. In the meanwhile, it was also realized that evaluating the benefit of this type of SM

systems in a monetary way can be hard in some cases. Therefore, in addition to ROI or life cycle analysis, more benefit evaluation approaches are needed to justify the adoption of SM technology.

This project includes:

1) Recognize and demonstrate successful systems for automated data collection and decision making
2) Develop system justification tool (other than ROI tool)
3) Standardize data framework for maintenance/preservation action and bridge damages reporting to support decision making (the data framework can be used for other bridges' data collection too)
4) Develop AI based data analysis approach for bridge condition evaluation and decision making.

**Topic: HRDI-BPM-02**

**Title: Bridge Preservation Technology Evaluation**

Bridge preservation has been widely used and proved to be a cost-effective way to extend bridge service life. However, quality control approach and effectiveness of each technology are not fully evaluated. Research is needed for each technology to:

1) Recognize best practice and standardize procedure (some have been done)
2) Standardize quality control approach
3) Evaluate of the effectiveness
4) Conduct ROI and LCCA (include environmental analysis if possible)
5) Predict deterioration after action (correction of base structural deterioration model)
6) Establish a standardized preservation action database

**Topic: HRDI-BPM-03**

**Title: Bridge Preservation and Management Enhancement with Digital Twins**

Digital twin is a relatively new technology in bridge community and current applications are focused on digital deliverables which represent the lifecycle of bridge design and construction.

Once bridge is built and open to traffic, operational mode is initiated in physical domain. Parallelly, in the digital domain, the digital as-built model will be passed into operational mode too. Data from all resources will be integrated to update the model and support decision making. Compared to traditional data model, the digital twin framework allows more information (e.g., 3D damage location information, etc.) to be stored and applied in performance evaluation and decision making. The research include:

1) Define bridge preservation/management work procedure
2) Define data requirements and data dictionaries
3) Update digital twin model with available data in a near-real time fashion
4) Use the digital twin model in bridge evaluation/preservation/management/operational decision making
5) Evaluate the ROI for adopting digital twin technology in bridge preservation/management

**Topic: HRDI-BPM-04**

**Title: A Holistic Approach: Integration of NDE with Bridge Preservation and Asset Management Practice**

Current bridge management and preservation decision making is mostly based on inventory data collected through mandated biennial bridge inspection and engineer judgment, sometimes supplemented by physical model analysis with material level parameters determined through lab testing. The component data provide the general performance condition of deck, superstructure, and substructure, which are important for asset management planning. Element data provide more granular information that is important for preservation decision making. Due to the requirements of MAP 21, most state established data-driven bridge management system. Some states also developed and integrated deterioration models and other action criteria into bridge management system for automated and optimized decision making.

Recent development in NDE technology provides a way to collect bridge performance data automatically, faster, with less traffic interference, and potentially more reliable. The data include the features that are typically used in visual inspection to determine the condition rating of components or condition status of elements, such as, crack, spall, delamination, etc. In addition, NDE data provide features that are not typically used in inventory data such as, cover

depth, corrosion condition, and corrosion potential etc. These feature data are very important for preservation decision making (especially for early intervention) and deterioration and remaining service life prediction too.

NDE technology has the potential for future automated data collection and automated decision making. A wider adoption can be achieved if the data reliability can be approved, and the data can be integrated into current management and preservation practice effectively and efficiently.

Currently NDE data have been used at project level to help engineers determine preservation/repair method and determine project quantity. However, how to integrate NDE data into current bridge management system and use them systematically in bridge management and preservation decision making is rarely researched and far from solved. As more and more DOT starting to collect more NDE data, there is a timely need to find an effective and efficient way to integrate NDE data into current bridge management and preservation practice.

There is a need for FHWA to establish an evaluation system that does a quantitative reliability analysis and can quantify the performance of NDE data collection module, data interpretation and analysis module, as well as operators' qualification. Standardize operation and data interpretation and analysis procedure is also important for data quality. Authorized recommendation for appropriate technologies for appropriate applications from FHWA will also help state DOTs find better way to collect data for more effective decision making. In this research, available NDE data (field and lab collected data) will be used in conjunction with inventory data to provide guidance to bridge owners on the reliability and probability of detection (POD) of NDE technologies to help them in comparing the cost/benefit ratio for different NDE technologies, selecting the appropriate technology for that application, and demonstrating the improvement in bridge asset management and preservation decision making using NDE data.

# Highway Construction Safety

**Topic: HRDI-HCS-01**

**Title: Assess Priorities for Highway Construction Worker Fatigue and Distraction**

Roadway construction depends on the safe management of vehicle traffic flow while simultaneously conducting construction work. As our highway infrastructure ages, many

transportation agencies are focusing on rebuilding and improving existing roadways. This means more roadwork is being performed on roadways that are open to traffic. At the same time, traffic continues to grow and create more congestion, particularly in urban areas. To avoid major queues during peak travel periods, transportation agencies are relying on night work. In addition, some projects are being constructed under compressed timeframes, which may create additional stress for workers. The combination of more work done alongside increasingly heavier traffic and greater use of night work can result in increased safety and fatigue considerations for highway workers. Added to this mix are increasing incidences of worker distraction while on the construction site brought upon from the increased use of smart phones and other technologies.

Historic emphasis of worker safety has focused on personal protection equipment, falls, electrocution, worker visibility to prevent runover/back-over and workers caught in between or struck by object accidents, temporary traffic control, law enforcement, and public awareness campaigns. Less emphasis has been placed on issues such as worker fatigue, work schedules, sleep patterns, rest, distractions, accelerated construction schedules, and their associated activities, nor their impacts on performance or potential performance measures. These issues have not been addressed to assess the unique hazards of transportation construction.

Goals of this research are to assess the current state of knowledge and state of practice of construction worker safety issues to better understand the priorities and gaps regarding worker fatigue and worker distraction on the job site to provide a baseline and data to support FHWA strategies, activities, and resources to address high priority items. It will result in an awareness of stakeholder worker safety issues and needs that require resources, efforts, and associated technology solutions and advancement focused exclusively on eliminating/minimizing these unique hazards of highway construction.

Efforts may lead to follow on activities based on findings; including commercial interest to provide robust solutions and fill in the identified gaps to current systems and technologies. The successful completion of this project will provide a strong foundation and data driven approach for specific follow up activities and initiatives for FHWA emphasis, development, and deployment of worker safety related items and technologies.

Assess the current state of knowledge and practice of construction worker safety issues to better understand the priorities regarding worker fatigue and, worker distraction on the job site to provide a baseline and data to support FHWA strategies, activities, and resources to address high priority items. Investigate, assess, document, and prioritize highway construction worker safety issues on fatigue and distraction and gain knowledge thru:

1. A comprehensive review to collect, assess, document, and prioritize worker fatigue and distraction safety issues.
2. Assess the current state of practice, available datasets, current and historical research, technologies, mitigation techniques and strategies, education and training efforts or campaigns on worker fatigue and distraction.
3. Develop state of the knowledge & assessment report and provide recommendations, priority, and rational for which worker fatigue and distraction needs or gaps are most urgent in highway construction.
4. Provide direct support and subject matter expertise related to efforts in highway construction worker safety issues on fatigue and distraction.

# Pavement Modeling and Performance (PMP)

**Topic: HRDI-PMP-01**

**Title: Electric Road System: Investigation of Inductive Charging Research Gaps and Implementation Challenges**

In January 2021, the President issued E.O. 14008, titled Tackling the Climate Crisis at Home and Abroad. 86 FR 7619 (Feb. 1, 2021). The President has directed the Federal government to use the full capacity of its agencies and implement a government-wide approach to address the climate crisis throughout the economy. Also, the recently passed Bipartisan Infrastructure Law (Public Law 117–58), aims to advance energy storage systems toward widespread commercial deployment and accelerate deployment of electric vehicles and charging stations that move us forward on the path toward a clean transportation future.

The electrification of the transport system has already started in the segment of light vehicles and more local and regional transports for the segments of heavy-duty vehicles. Electric Road System (ERS) is a relatively new technology that is under development and different technologies have reached different levels of maturity. Wireless power transfer to EVs through inductive charging has been identified as a technology that may support and enable even greater deployment of electric vehicles. Economical and efficient dynamic recharge of EVs can be achieved by embedding the energy source (a continuous transmitter) in the pavement system. On average, EV's can travel about 300-400 miles per charge. Dynamic wireless power transfer installed on interstate highways could make it possible for an EV conceivably travel from coast to coast without stopping to charge making the inconsistent availability of public charging stations less critical for EV implementation.

The aim of the first steps in the implementation process is to build up knowledge and the later steps are both to get more knowledge in real conditions and to prepare for a future roll out of an ERS system. In 2022, FHWA issued an RFI to ascertain the maturity of these technologies in the US and how the impacts to the roads they would be in are being considered. Based on the RFI responses, it became evident that the amount of knowledge on infrastructure implications of EV inductive charging system is very limited. This project aims to increase the body on knowledge on how inductive charging technology would change or impact the following:

- Pavement structural design (materials, layer thicknesses, joints, etc.)
    - Maximum distance to receiver, maximum depth of installation
- Pavement construction practices (initial, rehabilitation, and reconstruction)
    - Processes and/or potential for recycling of pavement materials.
    - Additional environmental considerations during construction.
- Preservation and/or maintenance requirements and practices.
- Pavement durability.

The first step will be to conduct an extensive literature to gather information on the state of knowledge and practice. The status of where in the process different nations are at implementing ERS differs over the world. There are between 10-20 nations that are somewhere in the process

between research to full scale implementation plans in some form. As part of this project, a report will summarize examples of activities at different level of implementation including:

- Challenges and experiences in the Planning process (including possibility to get permits and such things)
- Challenges and experiences in the design process
- Challenges and experiences in the construction process
- Challenges and experiences during operations

Overall, this project seeks to better understand the state of knowledge and development of wireless inductive EV charging technology and the implications of this technology for the highway transportation system. This project will lay out the foundation for future projects such as assessing infrastructure impacts in the field.

**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.