U.S. Department of Transportation
Federal Highway Administration
Turner-Fairbank
Highway Research Center

Progress Toward More Resilient Infrastructure

FHWA Resilience Efforts

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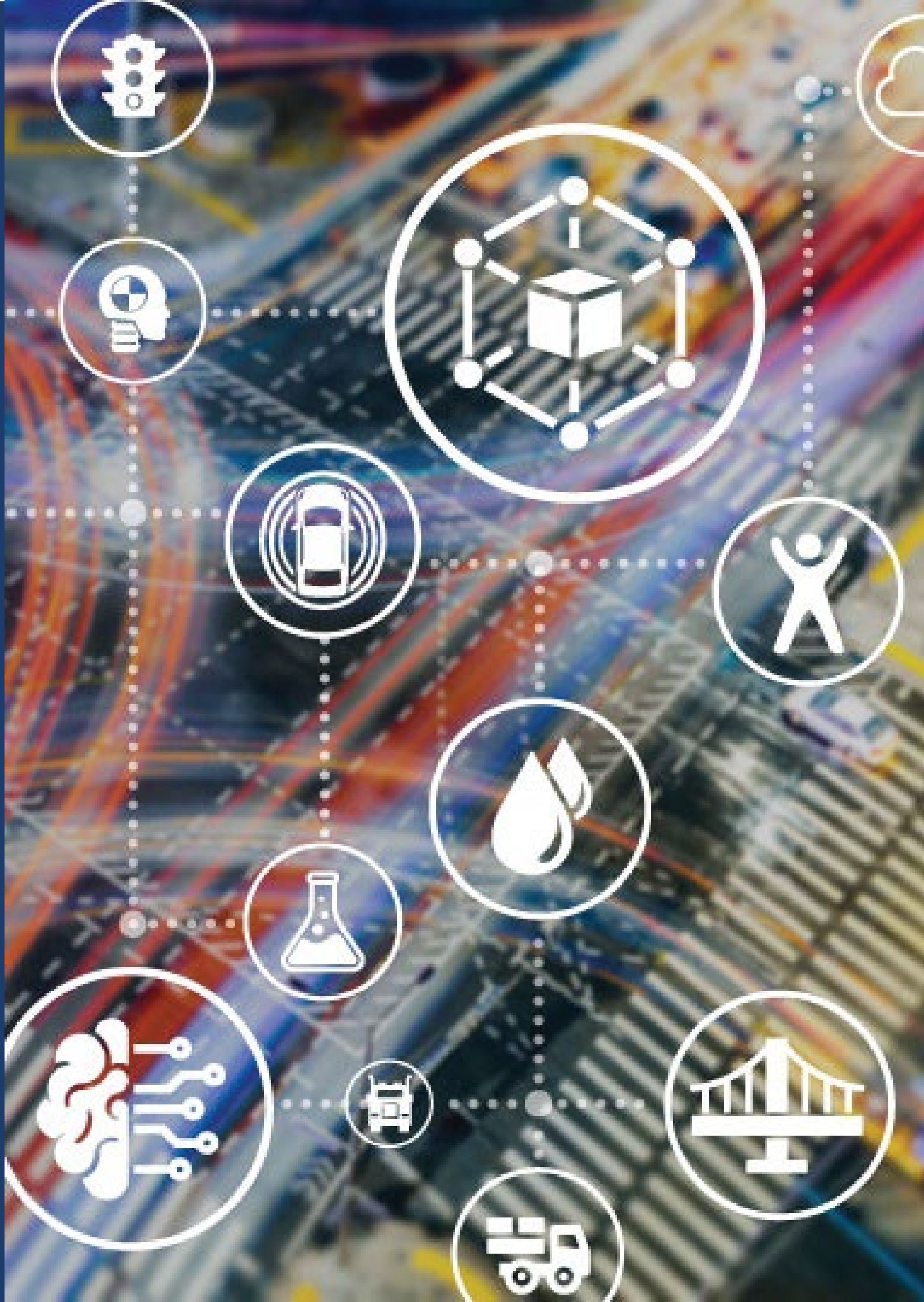
Office of Research, Development, and Technology
Federal Highway Administration (FHWA)

The Building Innovation Conference 2024
May 24th, 2024



Resilience is *not* sustainability

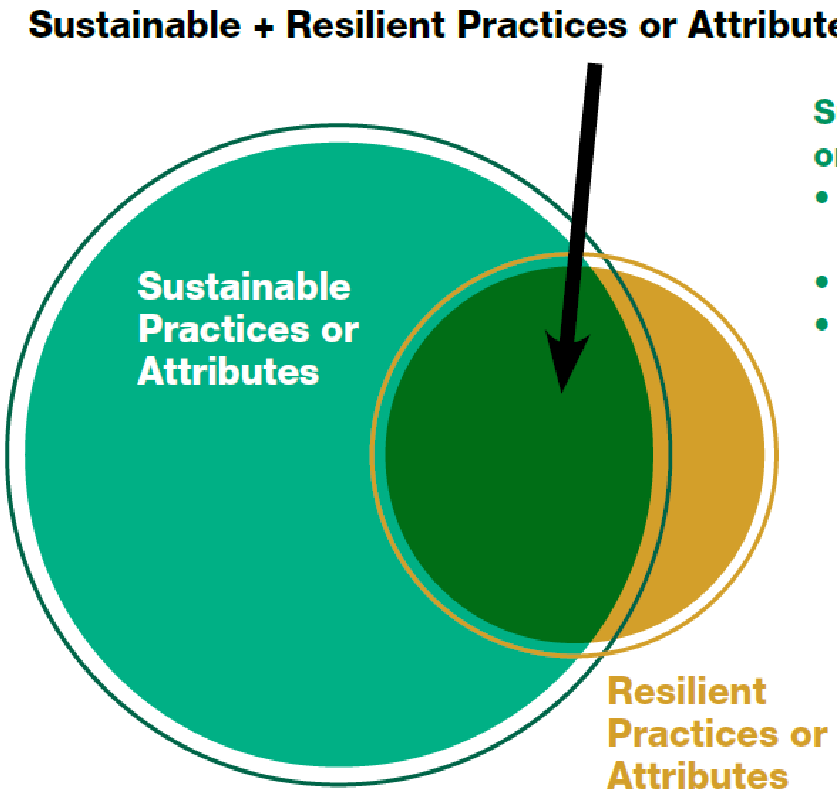


Figure 1. Venn Diagram of Sustainable, Resilient, and Resilient + Sustainable Practices and Attributes for Asphalt Pavements

Sustainable Practices or Attributes
- Use of recycled materials
- Cold Recycled Asphalt
- Asphalt mix and plant optimization

Sustainable + Resilient Practices or Attributes
- Warm Mix Asphalt (low emissions + increase in haul distance)
- Porous pavement systems (stormwater management + nuisance flooding)
- Perpetual Pavement Design
- Deep reconstruction of pavement (increase deep layer moduli)
- Rapid construction
- Ability to adjust pavement design to climate / climatic events to extend pavement life

Resilient Practices or Attributes That Are Not Sustainable
- Use of novel materials with unknown environmental or safety risks
- Use of climate adaptable materials when the social and environmental benefits do not outweigh the costs (e.g., use of polymer modified binders for low volume roads)
- Over-designing for low-risk catastrophic events

3owers and Gu (2021) "Resilient ɔhalt Pavements: Industry ˈutions for the Resilience Goal", PA SIP 105

Resilience is *not* sustainability

However…

While resilient solutions may or may not be sustainable… a resilient system contributes to sustainability…

What Is Resilience?

Resilience: The ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions, FHWA Order 5520 (FHWA 2014c).

1. (i) to resist hazards or withstand impacts from weather events and natural disasters; or (ii) to reduce the magnitude or duration of impacts of a disruptive weather event or natural disaster on a project; and
2. to have the absorptive capacity, adaptive capacity, and recoverability to decrease project vulnerability to weather events or other natural disasters. (Bipartisan Infrastructure Law, 2021)

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Environmental Impacts on Roadway

- Environmental factors contribute to pavement distresses, such as blowups, buckling, rutting, and thermal cracking.
- The Long-Term Pavement Performance Program studied environmental factor impacts on pavement performance (FHWA 2016b):
  - There is 36 percent of total damage for flexible pavements.
  - There is 24 percent of total damage for rigid pavements.
- Pavements are designed using climatic data; however, engineers typically assume stationarity.

Static Versus Future Climate Inputs

Stationary Climate Inputs:

- Based on historical data: Previously observed and measured.
- Grounded in well-established methods for design consideration.
- Based on the fundamental assumption: Historical data = future climate.

Future (Nonstationary) Climate Inputs:

- Generated by climate models: Partially incorporating historical inputs.
- Built on assumptions of greenhouse gas emission sources and levels.
- Based on the explicit assumption: Historical data ≠ future climate.

Data Sources for Future Climate Projections (Including Sea-Level Rise (SLR))

Resource	Description
Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections (DCHP) database (U.S. Federal Government 2021)	A database that contains publicly available, downloadable, downscaled climate projection data for temperature and precipitation in the contiguous United States.
USGS Geo Data Portal (U.S. Geological Survey 2022)	A web portal that provides access to a suite of climate datasets for temperature and precipitation, including climate projections using different downscaling techniques.
U.S. DOT CMIP Climate Data Processing Tool 2.0 (FHWA 2021a)	An Excel®-based tool to process data from the DCHP database to provide temperature and precipitation projections for climate variables relevant to transportation planners. The updated version uses the localized constructed analog dataset and incorporates several new variables.
U.S. Army Corps of Engineers Sea- Level Change Curve Calculator (U.S. Army Corps of Engineers 2021)	A web-based tool that accepts user input to produce a table and graph of the projected sea-level changes at the project site, including vertical land movement.
National Oceanic and Atmospheric Administration's (NOAA's) SLR Viewer (NOAA 2022)	A web mapping tool to visualize community-level impacts from coastal flooding or SLR that contains downloadable SLR data for many locations.

CMIP = Coupled Model Intercomparison Project; USGS = U.S. Geological Survey; DOT = department of transportation.

Possible Solutions for Roadway Vulnerabilities

Climate Change Stressors	Strategies
More Extreme Rainfall	Apply high-friction surface treatments. Use porous pavements or open-graded friction courses.
Higher Average Precipitation	Reduce moisture susceptibility of unbound base/subgrade materials through stabilization. Ensure asphalt mixtures' resistance to moisture susceptibility.
Wetter Winters and Drier Summers	Incorporate soil modification/stabilization into design. Use stiffer/improved pavement designs that are less susceptible to changes in subgrade properties. Ensure concrete freeze-thaw resistance. Ensure concrete in joint design remains below critical saturation.
Low Summer Humidity	Add asphalt binder antiaging additives. Pavement preservation to address binder aging. Reduce drying shrinkage of concrete mixes by decreasing paste volume. Consider concrete drying shrinkage in design by reducing slab length.
Higher Average Temperature	Raise asphalt binder grade or consider polymer modified binders. Exercise greater consideration of concrete coefficient of thermal expansion and drying shrinkage. Incorporate design elements to reduce damage from thermal effects in concrete pavements, including shorter joint spacing, thicker slabs, less rigid support, and enhanced load transfer.
Higher Extreme Maximum Temperature	Consider polymer-modified binders. Use shorter joint spacing in concrete designs. Keep joints clean and, in extreme cases, install expansion joints in existing pavements.
More Freeze-Thaw Events in Some Locations	Increase consideration of the thermal fatigue characteristics of asphalt binder.

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FHWA Resilience

Application to Infrastructure

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Resilience in TAMPs in Regulation

23 CFR Part 515.7

State DOTs are required to develop a risk-based asset management plan to include specific minimum processes, including the following section on lifecycle planning identified in subsection (b)*:

> A State DOT shall establish a process for conducting lifecycle planning for an asset class or asset subgroup at the network level (network to be defined by the State DOT). As a State DOT develops its lifecycle planning process, the State DOT should include future changes in demand; information on current and future environmental conditions, including extreme weather events, **climate change**, and seismic activity; and other factors that could impact whole-life costs of assets.

*Similar requirements are in subsection (c), which addresses risk management plans.

(Office of the Federal Register, National Archives and Records Administration 2018)

Adaptation Strategies: 1. Monitor Trends

Most predicted changes to environmental variables are projected to occur relatively slowly in relation to a typical infrastructure lifecycle (FHWA 2015).

Key pavement indicators to monitor for climate change impacts.

Asphalt Pavement Indicators	Concrete Pavement Indicators
Rutting of asphalt surface	Blow-ups (JPCP)
Low temperature (transverse) cracking	Slab cracking
Block cracking	Punch-outs (CRCP)
Raveling	Joint spalling
Fatigue cracking and pot holes	Freeze-thaw durability
Rutting of subgrade and unbound base	Faulting, pumping, and corner breaks
Stripping	Slab warping
	Punch-outs (CRCP)

Source: FHWA.
(FHWA forthcoming b.)

CRCP = continuously reinforced concrete pavement; JPCP = jointed plain concrete pavement.

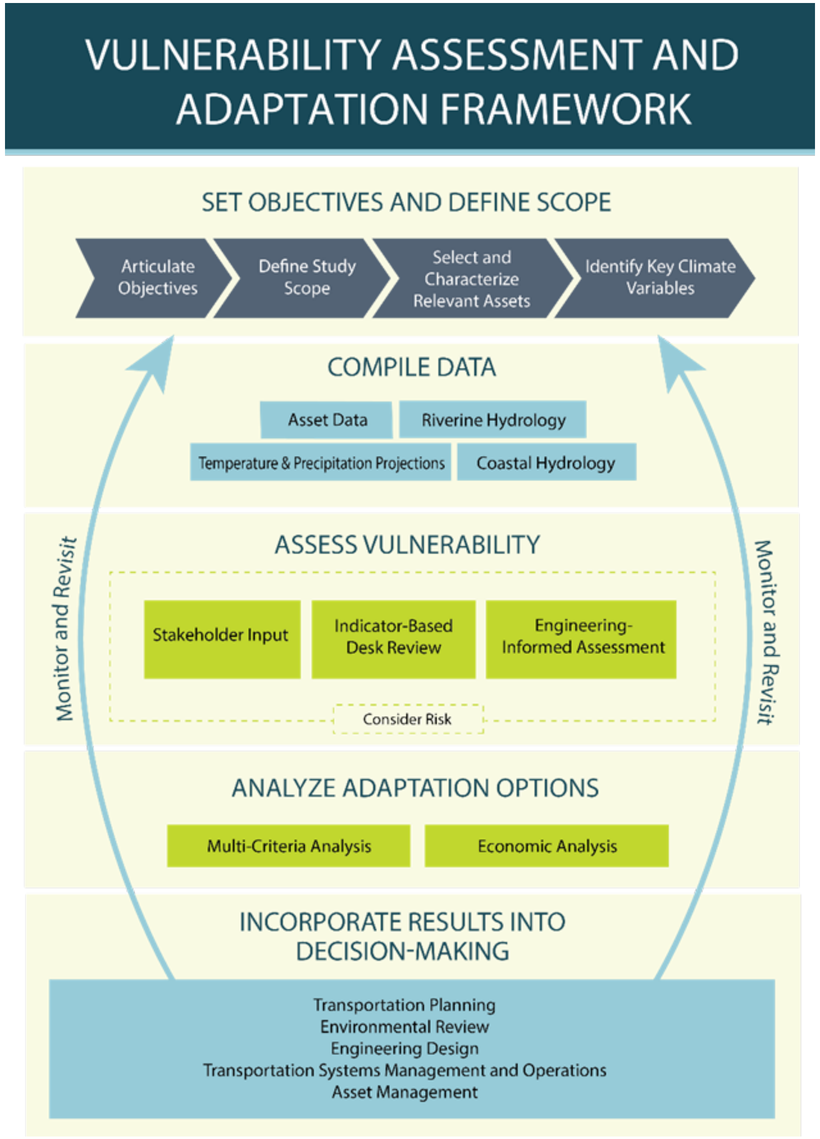
2. When Trends Differ, Evaluate Vulnerability

Objectives:

- ► Identify whether an asset is more vulnerable than other system assets.
- ► Prioritize potential vulnerabilities for the system.

Approach:

- ► Use the Vulnerability Assessment Scoring Tool (FHWA 2017e).
- ► Input local asset data.
- ► Output the relative vulnerability scores per asset.



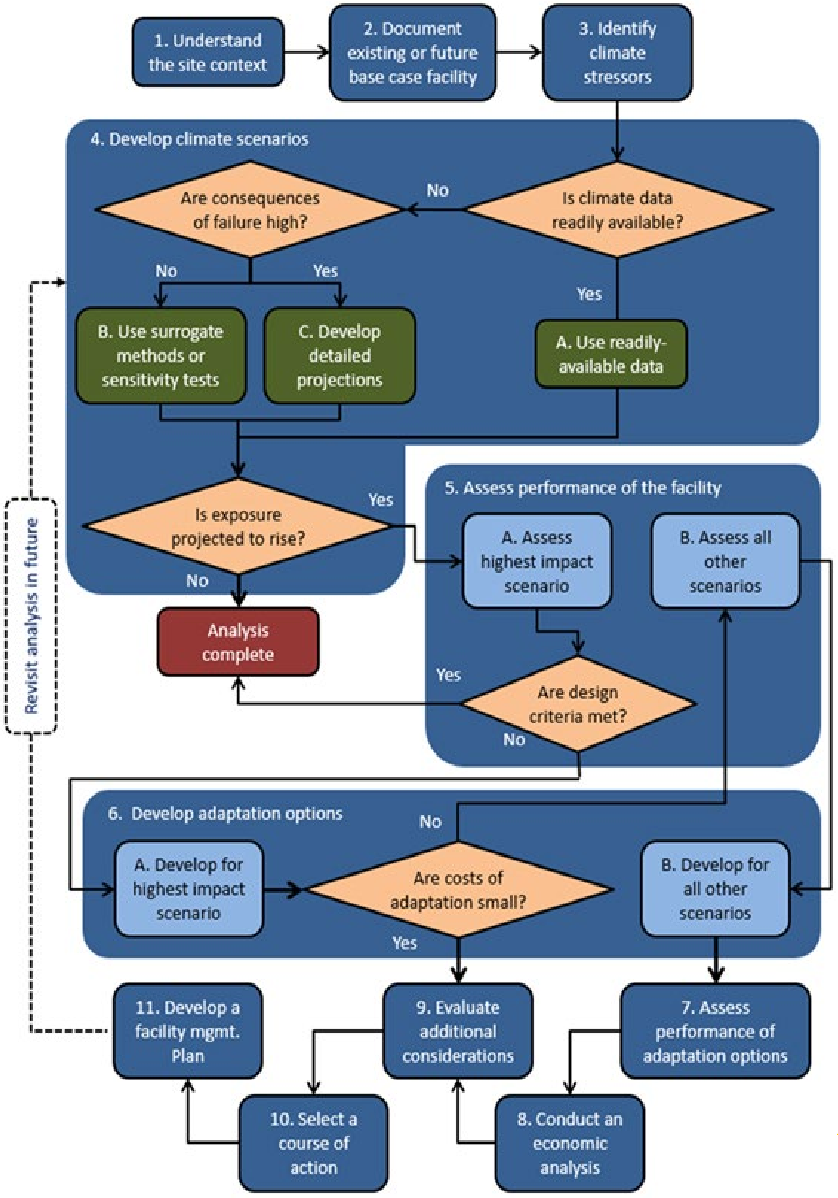
Source: FHWA.

(FHWA 2019)

3. Plan and Design Infrastructure to Meet Future Conditions:

- Use the adaptation decisionmaking assessment process (ADAP).
- Use a risk-based approach for planners, designers, or engineers.
- Tailor to each State.
- Aid decisionmakers in determining which project alternative is best (lifecycle costs, resilience, and regulatory and political settings) (FHWA 2021b).

Decision Tree of the ADAP Steps



Source: FHWA.
(FHWA 2016a)

FHWA Resilience

Ongoing Efforts

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PROTECT Discretionary Grant Program Overview

- **Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation** (PROTECT) Discretionary Grant Program: Established under the Bipartisan Infrastructure Law, Section 11405; 23 U.S.C. 176.

- **Program purpose**: To plan for and strengthen surface transportation to be more resilient to natural hazards, including climate change, sea level rise, flooding, extreme weather events, and other natural disasters through competitive discretionary grants.

- **Total available in FY 2022 and FY 2023**: $848 million (Discretionary Grant Notice of Funding Opportunity, April 2023 NOFO))

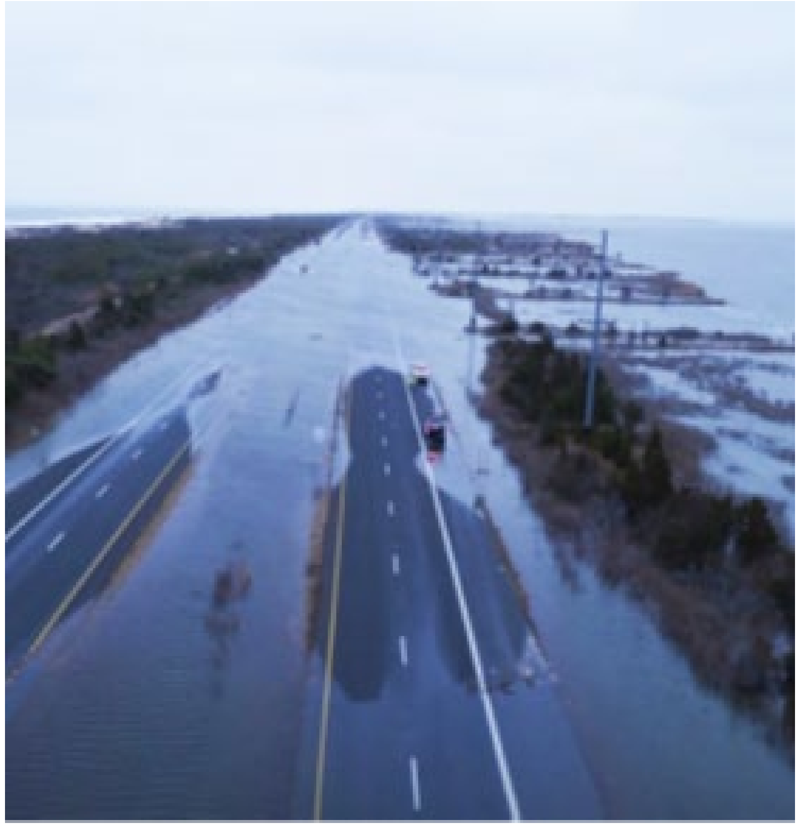
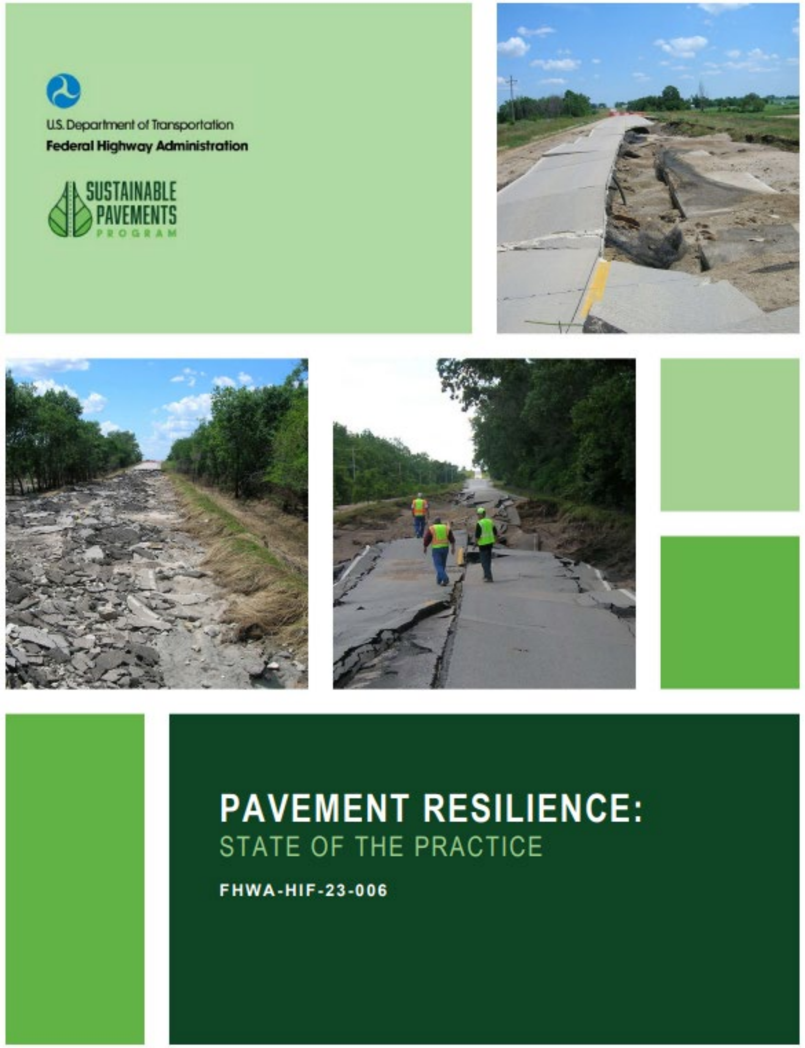


Photo credit: Delaware DOT

Infrastructure Resilience Roadmap

- What are the current gaps and future needs?
  - Resilience peer exchanges.
  - Highway resilience to wildfire events.

- What education resources are available to incorporate more resilient practices?
  - Pavement resilience technical guidelines (Recently Published).



Assessing Flooded Roadway Project

- Project objectives:
  - Develop methods to assess flooded pavements.
  - Assess the capacity to carry traffic during/after flooding.
  - Evaluate emergency or heavy equipment.
  - Evaluate normal traffic.
  - Determine the tradeoff between the user costs of road closure (and detours) versus the costs of increased road damage.
  - Develop a decision support tool.
- Project deliverables: A report is in publication (FHWA forthcoming a).

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National Oceanic and Atmospheric Administration Project: Effects of Sea Level Rise

- Joint project with the National Centers for Coastal Ocean Science.
- Project goal details: Facilitate informed adaptation planning and coastal management decisions through a multidisciplinary research program that results in integrated models and tools of dynamic physical and biological processes capable of evaluating vulnerability and resilience under multiple SLR, inundation, and management scenarios.

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NOAA Project (Continued)

Two focus areas:

- Coastal resilience.
- **Surface transportation** resilience:
  - Quantify the vulnerability of surface transportation systems to SLR and inundation.
  - Quantify the social, economic, and/or ecological benefits.
  - Predict the effects of SLR and inundation on surface transportation infrastructure under varying risk mitigation and management strategies.

Impacts of Wildfires on Transportation Assets

- Project objectives:
  - Determine the state of knowledge of wildfire impacts on pavements and other assets.
  - Define direct and indirect impacts.
  - Identify research gaps and needs.
- Project deliverables:
  - Determine the state of knowledge.
  - Identify how State DOTs deal with this issue:
    - Conduct detailed interviews.
    - Gather information on their experiences, observations, and challenges.

Impacts on Pavements

- Surface damage: melted pavement, potholes, raveling, delamination
- Structural damage due to increased traffic loadings (number and magnitude) from fire suppression and post-fire cleanup
- Damage due to post-fire flooding (washout and debris flow, reduced structural support, loss of structural capacity)

Source: © 2022 NCE

Wildfire Impact - Indirect

PERMEABLE PAVEMENTS: Report to Congress

- Background
- Stormwater management
- Permeable pavement systems
  (Definition, types, design, and maintenance)
- Implementation and case studies
- Economic & environmental impacts
- Challenges & opportunities
- Knowledge gaps and recommendations

Information collected from ~ 305 references

Report to Congress – Table of Contents

Summary

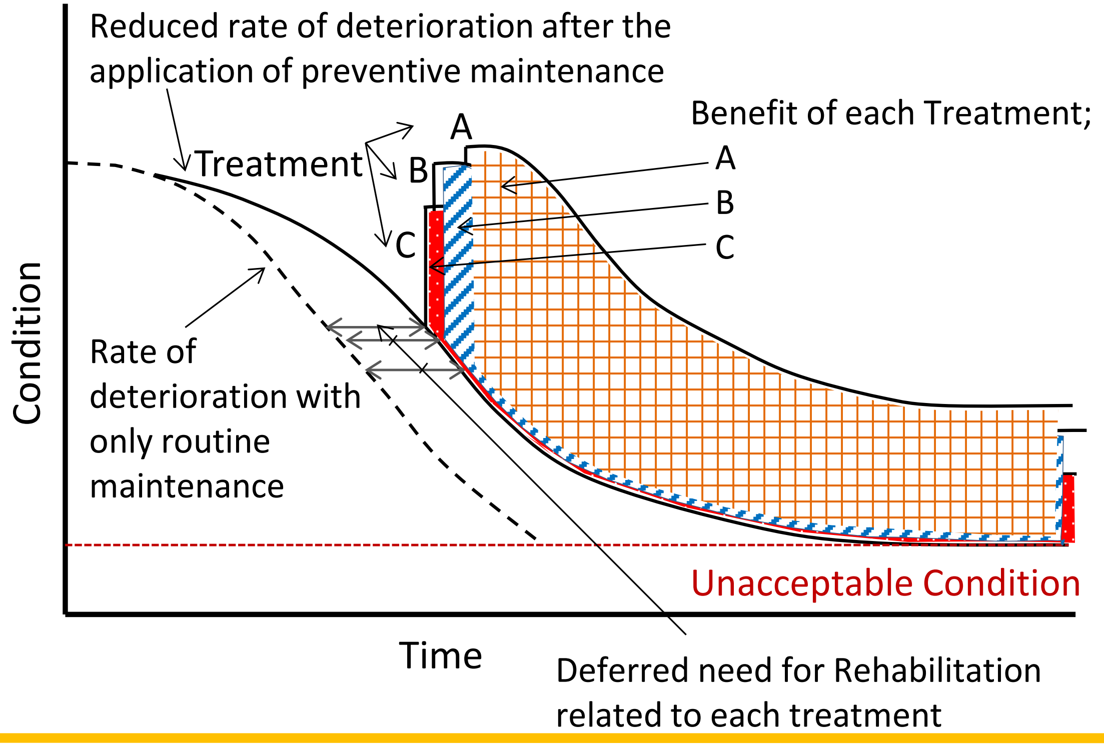
- **General Consideration**
  a. Generally, more expensive to construct
  b. Sustainability impacts & benefits: water quality and heat island impacts
  c. Resilience: reducing freeze–thaw damage

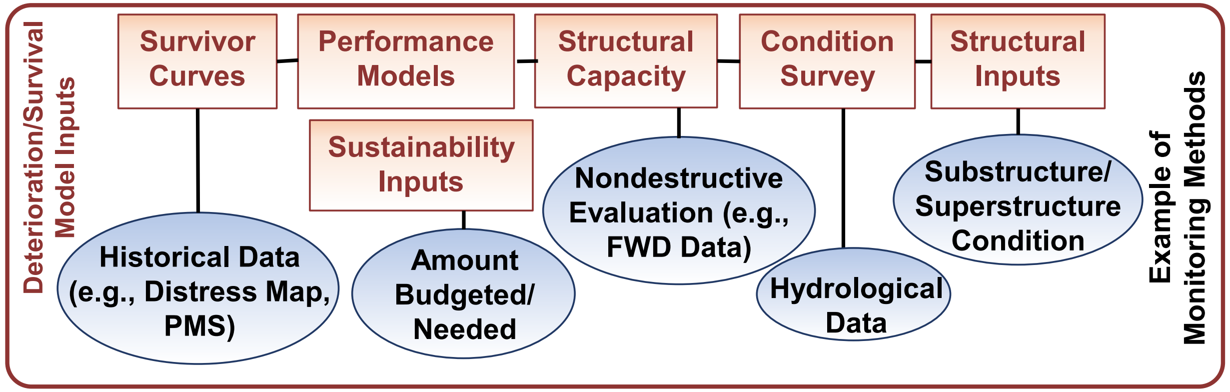
- **Advantages**
  a. Lowering the amount of water runoff
  b. Increasing traffic safety: enhanced tire–pavement traction & minimizing hydroplaning

- **Knowledge Gaps**
  a. Economic impact
  b. Design optimization and structural capacity
  c. Infiltration measurements and lack of hydrologic models
  d. Lack of data on quantifying life-cycle assessment and life-cycle cost analysis
  e. Long-term performance

Upcoming Projects/Efforts

- Impact of Environmental Factors on Transportation Infrastructure—Different datasets will be used for the development of deterioration models.





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Upcoming Projects/Efforts

- Dissemination of Available Knowledge on Infrastructure Resilience—A series of technical webinars, workshops, and a TechBrief.

- Holistic Framework for Project-Level Resilient Roadway Adaptation and Engineering Design—Future climate projection incorporation for resilient mechanistic-empirical pavement design.

NEW: Transportation Pooled Fund on Resilience

New Pooled Fund Project (TPF-5(512)):
Resilience Approaches for Roadway Assets

TPF TRANSPORTATION POOLED FUND

About Solicitations Studies Tools Help

Transportation Pooled Fund - Study Detail

Home › Studies › Resilience Approaches for Pavements and Geotechnical Assets

Resilience Approaches for Pavements and Geotechnical Assets

Print

General Information

Study Number:	TPF-5(512)
Former Study Number:	
Lead Organization:	Virginia Department of Transportation
Solicitation Number:	1590
Partners:	FL, HI, MDOT SHA, PADOT, TX, VA, WA
Status:	Cleared by FHWA
Est. Completion Date:	
Contract/Other Number:	
Last Updated:	Apr 27, 2023
Contract End Date:	

Financial Summary

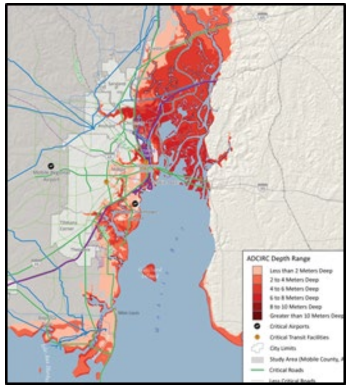
Contract Amount:	
Suggested Contribution:	
Total Commitments Received:	$660,000.00
100% SP&R Approval:	Approved

Contact Information

Lead Study Contact(s):	Shabbir Hossain Shabbir.Hossain@VDOT.Virginia.gov Phone: 434-293-1989
FHWA Technical Liaison(s):	Amir Golalipour amir.golalipour@dot.gov Phone: 2024933089

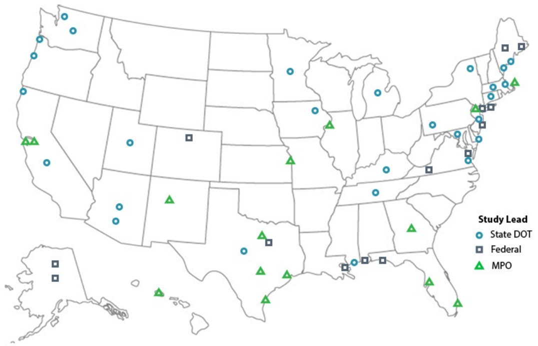
FHWA Resilience Resources

Gulf Coast 2 Study



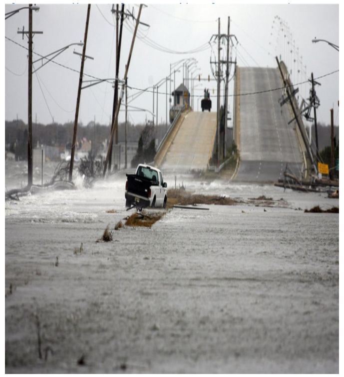
(FHWA 2019)

Resilience Pilots with State DOTs and MPOs



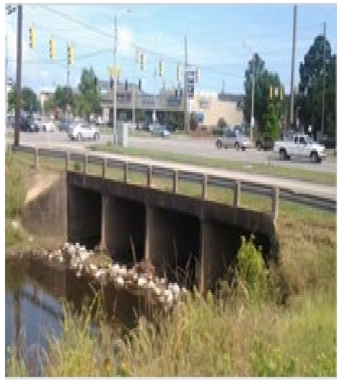
(FHWA 2021c) MPOs = metropolitan planning organizations.

Hurricane Sandy Project



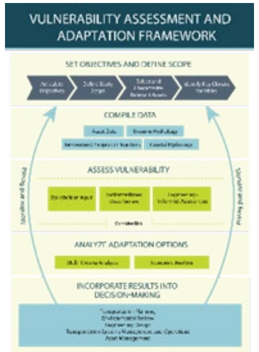
(FHWA 2017c)

Engineering Assessments



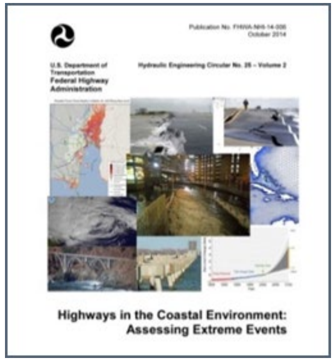
(FHWA 2017d)

Vulnerability and Adaptation Framework



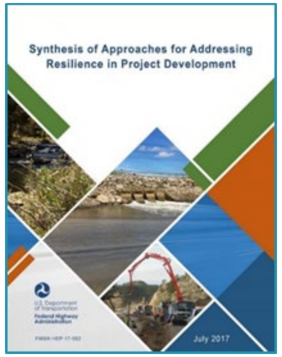
(FHWA 2019)

Engineering Guidance (HEC-25 & 17)



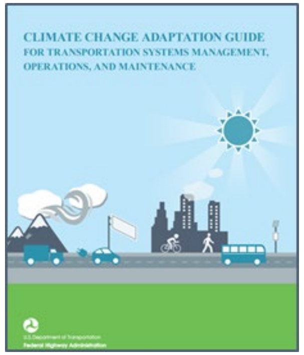
(FHWA 2014a)

Project Development



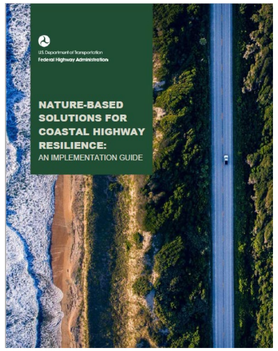
(FHWA 2015)

Operations and Maintenance



(FHWA 2017a)

Nature-Based Solutions



(Buckingham and Torossian 2021)

All photos source: FHWA.

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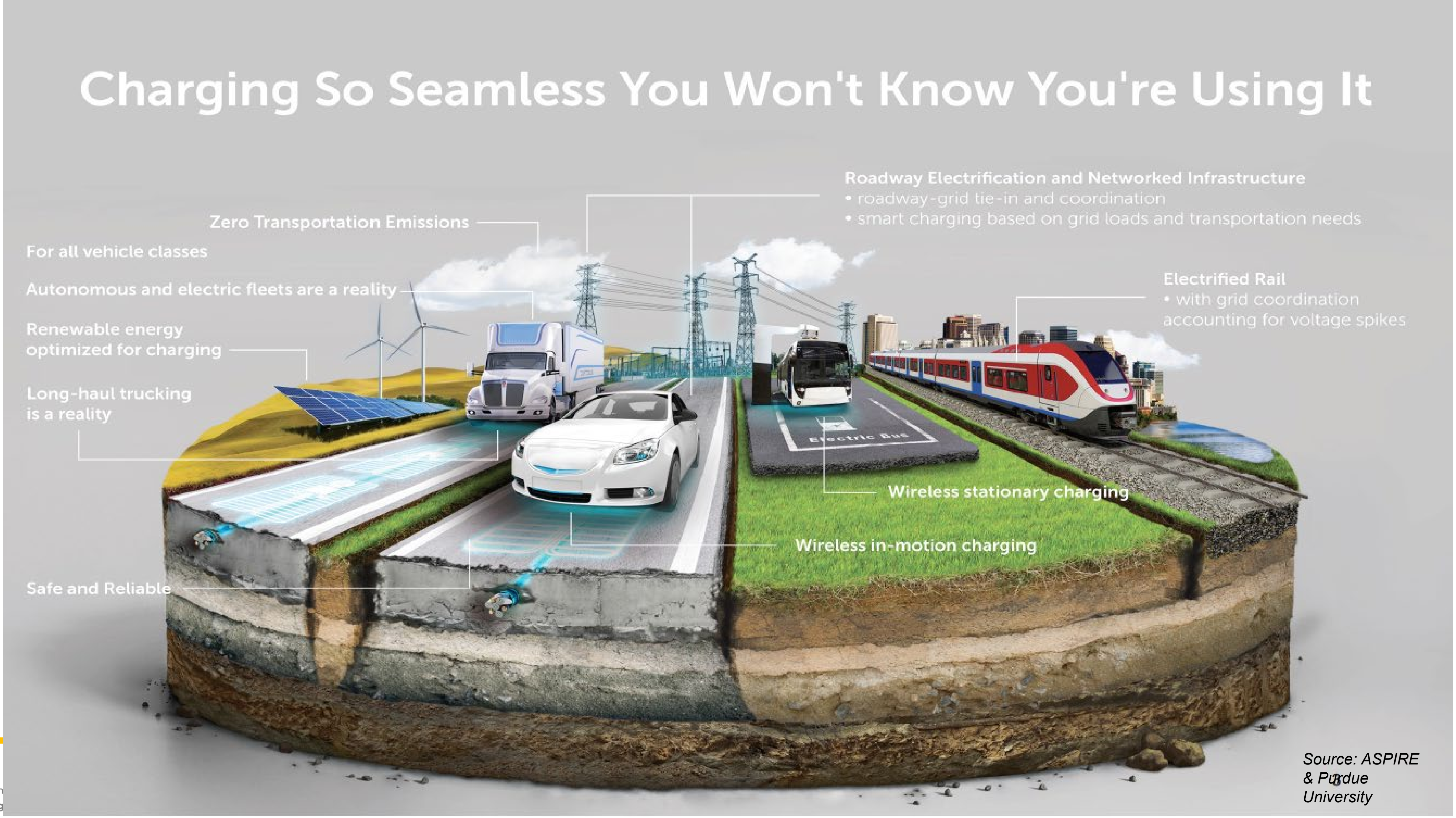
Inductive Charging

Application to Roadway

U.S. Department of Transportation
Federal Highway Administration
Turner-Fairbank Highway Research Center

Electric Vehicles (EV) Charging



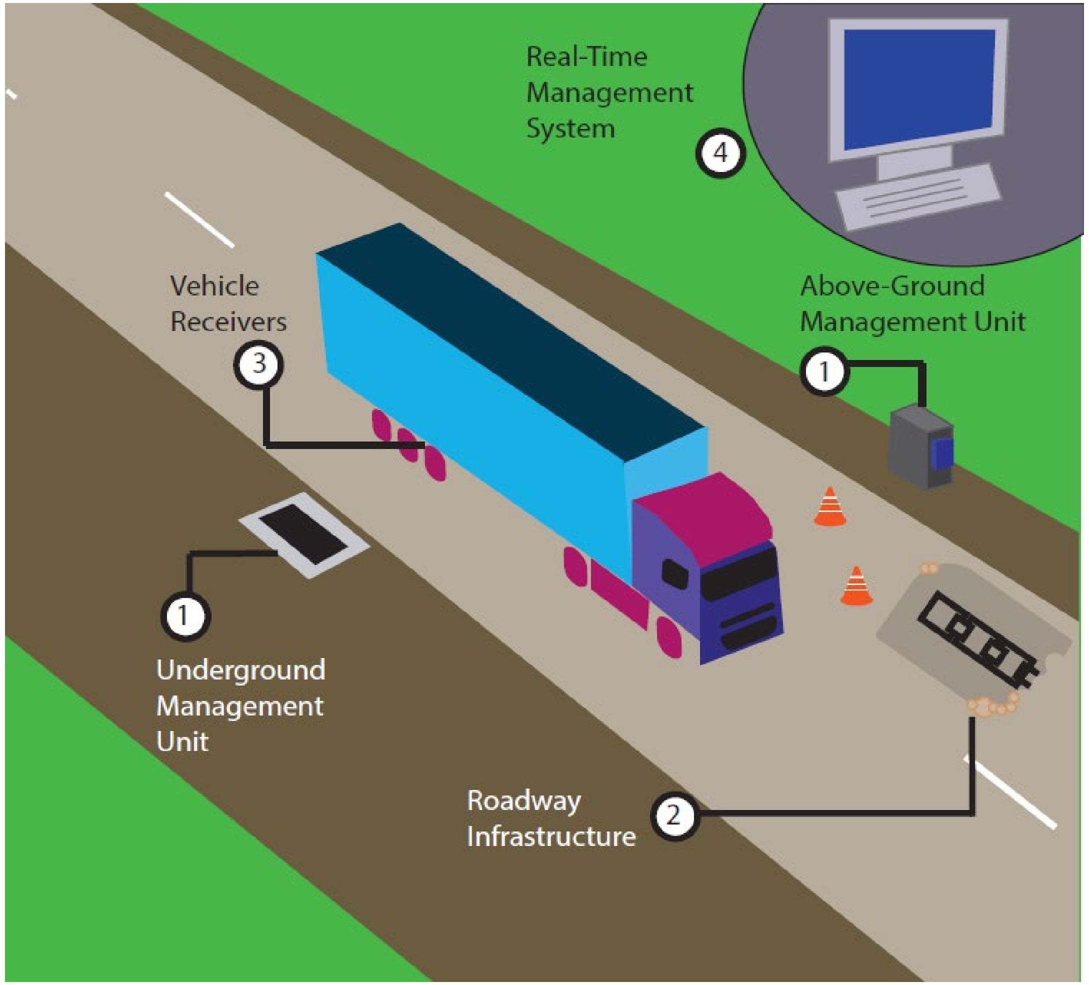
Source: ASPIRE & Purdue University

Charging Solutions & Technologies

- **Dynamic charging:** wireless electric roads to charge vehicles in-motion along their daily routes, e.g. buses, delivery vans and other vehicles.
- **Semi-dynamic charging:** for slow-moving vehicles (e.g. queuing taxis waiting for passengers, entry to logistics hubs and ports, traffic lights, bus stopping to drop off/pick up passengers)
- **Static charging:** stationary charging at bus terminals, garages and depots, distribution facilities, loading/unloading docks, parking lots and street parking.

Different Components: Ground Based and Vehicle Based

1. Management unit (MU): Above-ground or underground placement. MU safely transfers energy from the grid to the charging infrastructure underneath the road surface.
2. Roadway infrastructure: Under-road copper coils, which transfer power to the vehicles' receivers. The system is installed under the driving surface, allowing for unobstructed resurfacing.
3. Vehicle receiver(s): Energy transmitted directly to the battery and engine. The modular design with multiple receivers can be integrated into large commercial vehicles to support higher power transfer rates. Typically, private vehicles require one receiver, vans two receivers, buses three receivers, and trucks can have up to seven receivers.
4. Real-time management system: A cloud-based system that monitors and manages optimal EV charging at fleet scales. This system allows for remote troubleshooting, diagnostics, and data reporting.
5. Vehicle control unit: A safe and optimized charging solution enabled through communication with the vehicle management systems.



Source: FHWA.

Example: Roadway Deployment

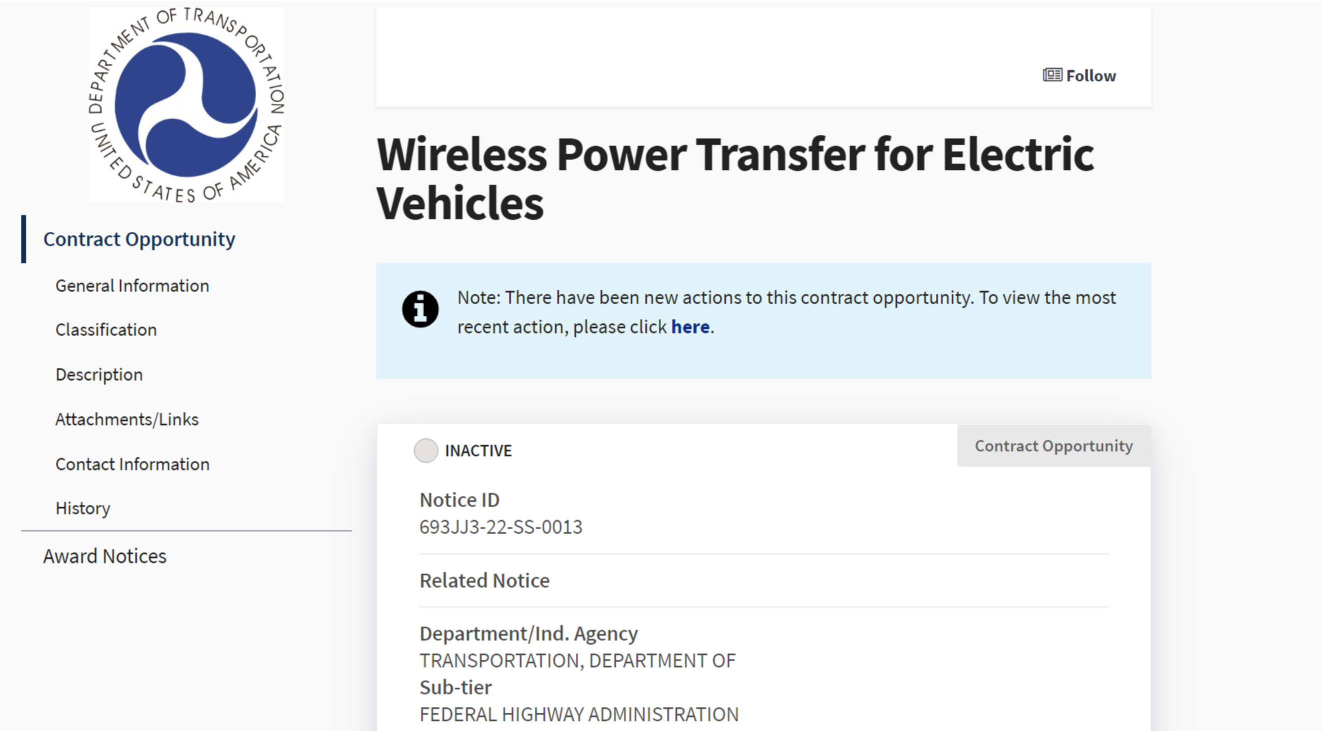
Source: Electreon

RFI: Wireless Power Transfer for Electric Vehicles

Notice ID:693JJ3-22-SS-0013

This Sources Sought Notice is not a request for formal proposals or quotes.

The Federal Highway Administration is soliciting information from the public and a broad array of stakeholders across public and private sectors that may be familiar with or interested in **development** and/or **manufacturing** and assembly of *wireless inductive EV chargers* and their deployment.



Source: https://sam.gov/opp/8cb2e2934fd34deaac51b5fe7d82334e/view

Link to Roadway Design & Management

Infrastructure Implications:
For each dynamic EV inductive charging system identified, what is the expected nature and extent of changes or impacts of that system on a typical asphalt or concrete pavement in which it is installed with respect to 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.

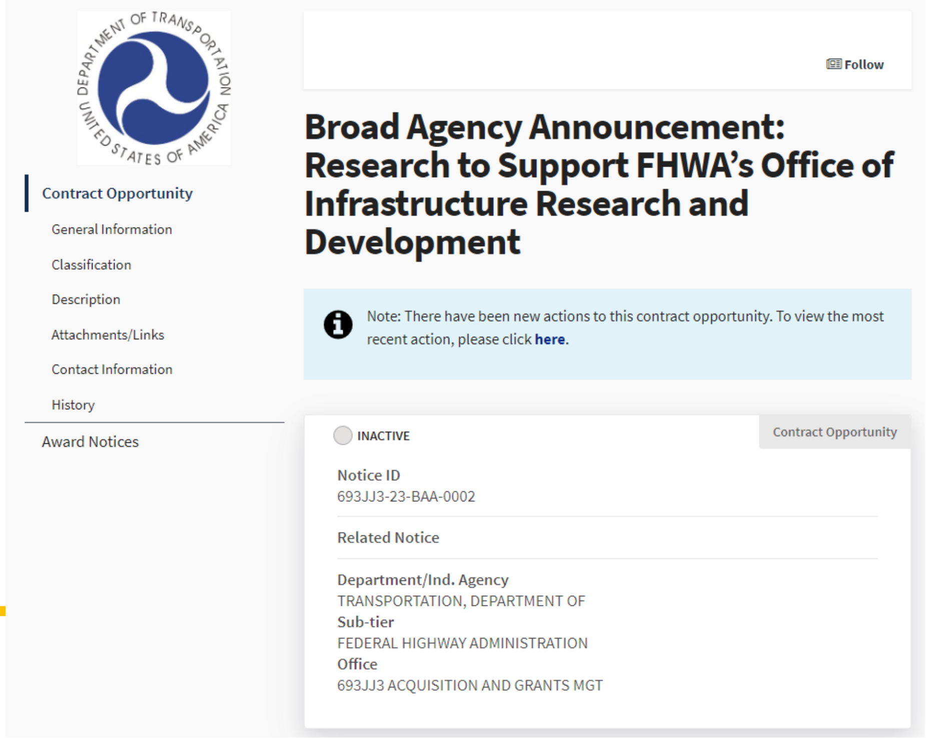
Link to Roadway Design & Management – Cont.

- **Preservation and/or maintenance requirements and practices.**
- **Pavement durability.**
- **Expected in-service durability and reliability of inductive charging infrastructure.**
- **Decommissioning or replacement of charging technology**

We need to find answers to these questions…

New Research Project

- **<u>Electric Road System</u>**: Investigation of Inductive Charging Research Gaps and Implementation Challenges
  - Identify knowledge and implementation gaps.
  - Evaluating proposals under Broad Agency Announcement (BAA).
  - Search for federal or state partners.



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