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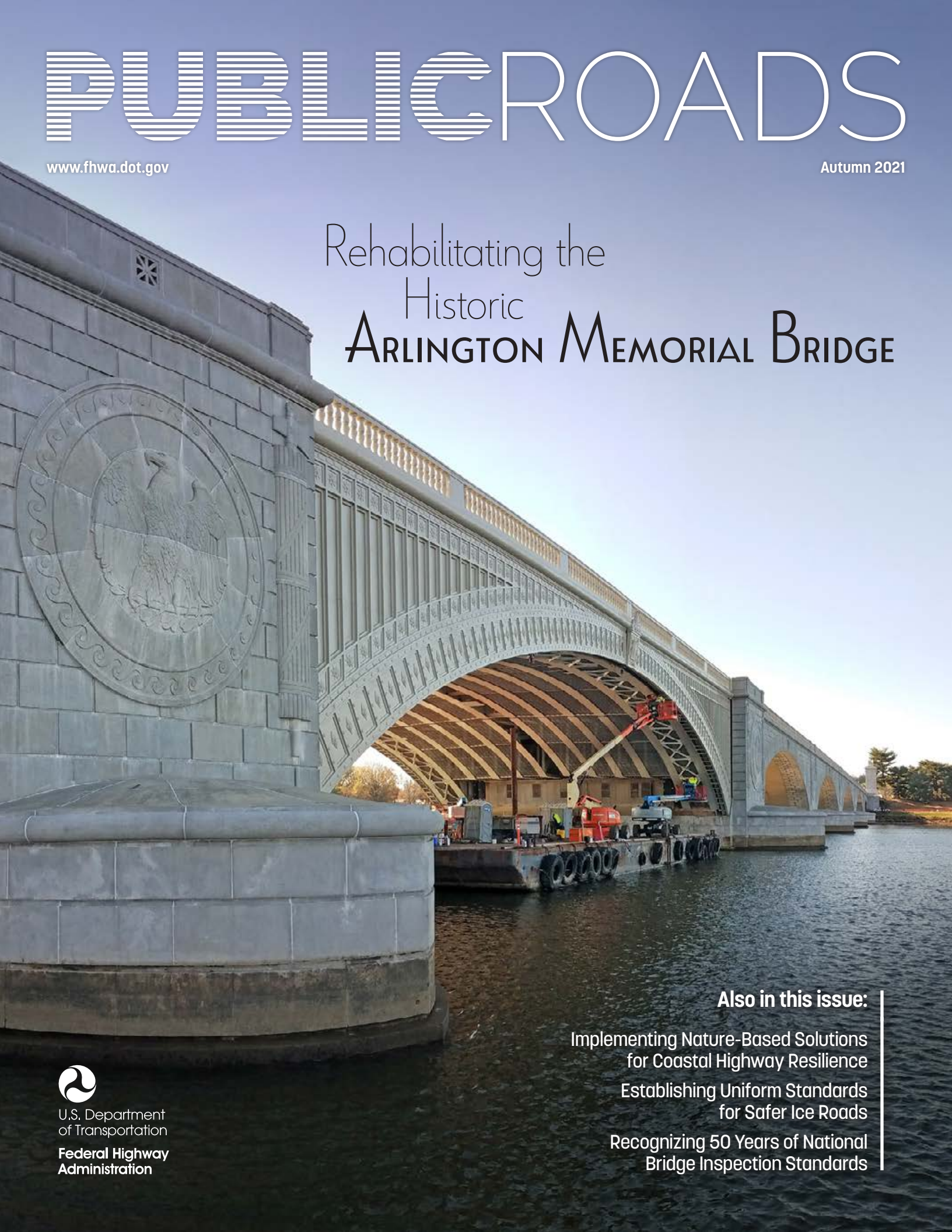

Rehabilitating the Historic Arlington Memorial Bridge

Also in this issue:

Implementing Nature-Based Solutions for Coastal Highway Resilience

Establishing Uniform Standards for Safer Ice Roads

Recognizing 50 Years of National Bridge Inspection Standards

U.S. Department of Transportation

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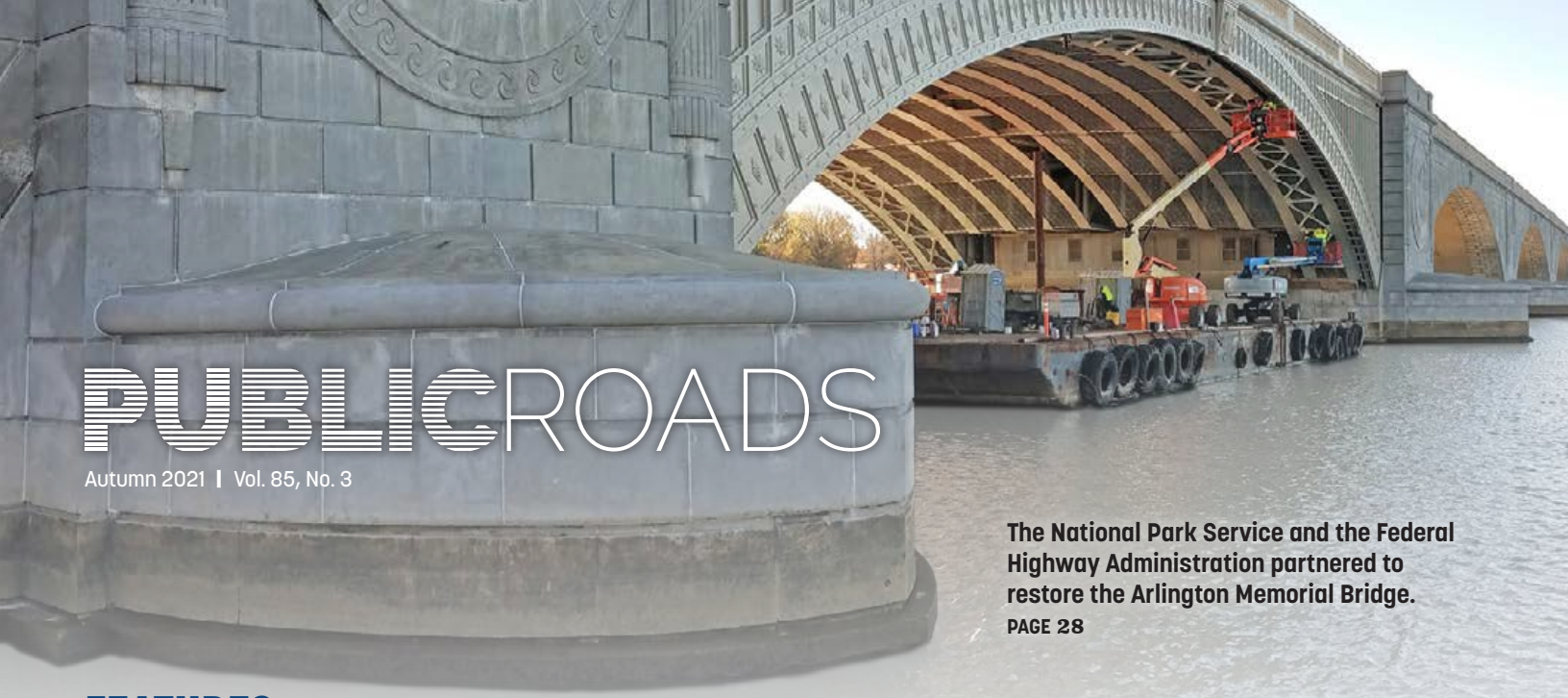
Autumn 2021 | Vol. 85, No. 3



The National Park Service and the Federal Highway Administration partnered to restore the Arlington Memorial Bridge.
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FEATURES

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© Arizona Department of Transportation.

DEPARTMENTS

FRONT COVER and ABOVE–The project team used floating barges to help with the rehabilitation of the Arlington Memorial Bridge.

BACK COVER–The rehabilitation project considered historic architectural details, like the decorative fascia shown being removed, to be important features to preserve and restore.

Source: FHWA.

U.S. Department of Transportation
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Public Roads (ISSN 0033-3735; USPS 516-690) is published quarterly by the Office of Research, Development, and Technology, Federal Highway Administration (FHWA), 6300 Georgetown Pike, McLean, VA 22101-2296. The business and editorial office of Public Roads is located at the McLean address above. Phone: 202-493-3375. Fax: 202-493-3475. Email: lisa.a.shuler@dot.gov. Periodicals postage paid at McLean, VA, and additional mailing offices (if applicable).

POSTMASTER: Send address changes to *Public Roads*, HRTM-20, FHWA, 6300 Georgetown Pike, McLean, VA 22101-2296.

Public Roads is sold by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. Requests for subscriptions should be sent directly to New Orders, Superintendent of Documents, P.O. Box 979050, St. Louis, MO 63197-9000. Subscriptions are available for 1-year periods. Paid subscribers should send change of address notices to the U.S. Government Printing Office, Claims Office, Washington, DC 20402.

The electronic version of *Public Roads* can be accessed through the Turner-Fairbank Highway Research Center home page (https://highways.dot.gov/research).

The Secretary of Transportation has determined that the publication of this periodical is necessary in the transaction of the public business required by law of this department.

All articles are advisory or informational in nature and should not be construed as having regulatory effect.

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For more information, representatives of the news media should contact FHWA's Office of Public Affairs at 202-366-0660.

Recommended citation: Federal Highway Administration, *Public Roads*, Autumn 2021 (Washington, DC: 2021) https://doi.org/10.21949/1521676

Challenges and Opportunities

Source: FHWA.

2021 has been a busy year at the Federal Highway Administration. We are all excited about the new opportunities created by new leadership at the White House and throughout the Department of Transportation, as well as by congressional interest both in reauthorizing surface transportation funding and enacting a bipartisan infrastructure bill. Even though I've only been with FHWA for several months, it's been a busy and exciting time.

This issue of *Public Roads* spotlights bridge safety—from the history, decline, and recent recovery of the century-old Arlington Memorial Bridge in Washington, DC, to an article about the 50th anniversary of the National Bridge Inventory System, which has kept all public bridges safe since the tragic collapse of the Silver Bridge in West Virginia in 1967. Shining a light on the importance of bridge inspections is especially timely, given the fracture discovered in May on the Hernando DeSoto Bridge over the Mississippi River between Tennessee and Arkansas.

This year featured many historic milestones, including the Interstate system's 65th birthday on June 29. Such occasions prompt many to look back and reminisce about the difficulties of travel before the age of the superhighway. While we all can and should learn lessons from the past, we also must look to the future. How will the Nation be better because of the decisions and investments we make today? When others look back 65 years from now, how will they judge the work we are doing in 2021?

For me, one topic that raises those very questions is our response to the climate crisis. The recent report by the Intergovernmental Panel on Climate Change is a stark reminder that no matter how much we work to reduce greenhouse gas emissions, we must also make our transportation infrastructure more resilient to the heat, precipitation, and sea level rise already locked in by climate change. Weather has been a significant factor in the safety of the traveling public this year—from a week of extreme heat over the Pacific Northwest that caused roads to buckle, to the flash floods and mudslides that closed I–70 through Glenwood Canyon in Colorado. This issue of *Public Roads* focuses on strategies used to respond to unusual weather, as well as coastal resilience and Arizona's massive dust storms.

Making the Nation's roads safer and more resilient to a changing climate are only two of the challenges we face as we work to Build Back Better. We seek a transportation system that is safe, reliable, equitable, sustainable, and resilient—but with each challenge comes opportunity. Each problem invites creative new solutions.

While new to the job, it's already clear to me that FHWA is a problem-solving agency that is up to these challenges and eager to take advantage of new opportunities. It's also clear that we will not succeed alone but by collaborating with our State and local partners, advocates, and stakeholders. Indeed, I believe that facing the challenges ahead together will prove to be the greatest opportunity of all.

Stephanie Pollack
Acting Administrator
Federal Highway Administration

Simplifying Environmental Reviews and Collaboration with INPCT

Source: FHWA.

by **MEGAN COGBURN** and **DAVID WILLIAMS**

The Federal Highway Administration is on the cutting edge of efforts to accelerate project delivery. To help save time and simplify the environmental documentation required by the National Environmental Policy Act (NEPA), FHWA created the Interagency NEPA & Permitting Collaboration Tool (INPCT). A rebranded and improved version of FHWA's eNEPA, INPCT is a web-based collaboration tool designed to aid NEPA practitioners in efficiently managing the environmental review and permitting processes for all types of transportation projects, from simple Categorical Exclusions to more complex Environmental Assessments and Environmental Impact Statements.

More than 400 participants attended the webinars launching INPCT, hosted by FHWA's Office of Project Development and Environmental Review in May and June 2021. Attendees included representatives from 37 State departments of transportation, 33 FHWA division offices, other USDOT modal administrations, 6 other Federal agencies, and multiple metropolitan planning organizations and consulting firms.

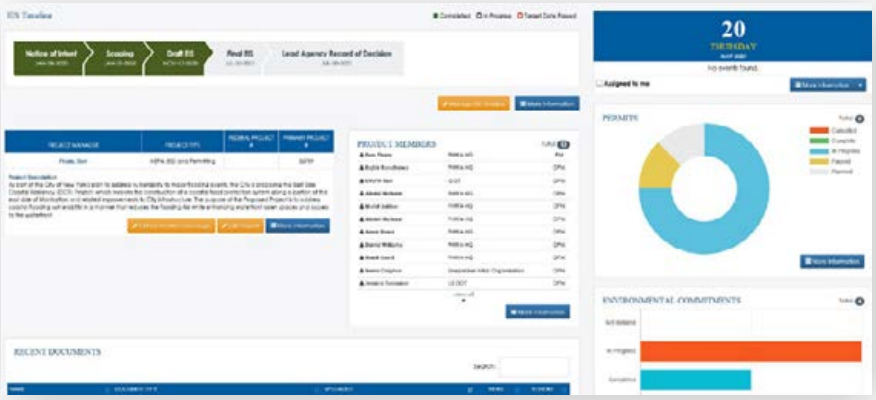
Housed behind FHWA's firewall, INPCT provides a secure web-based platform. The tool can help strengthen interagency collaboration during the NEPA process by making it easier for project managers, environmental planners, and resource and regulatory agency staff to exchange documents and collect and share comments in real time. INPCT centralizes the many elements of a NEPA review to help seamlessly manage the decisionmaking process. Through its user-friendly interface, users can track project and permitting schedules and key milestones, send meeting invites, manage documents, and even track mitigation commitments.

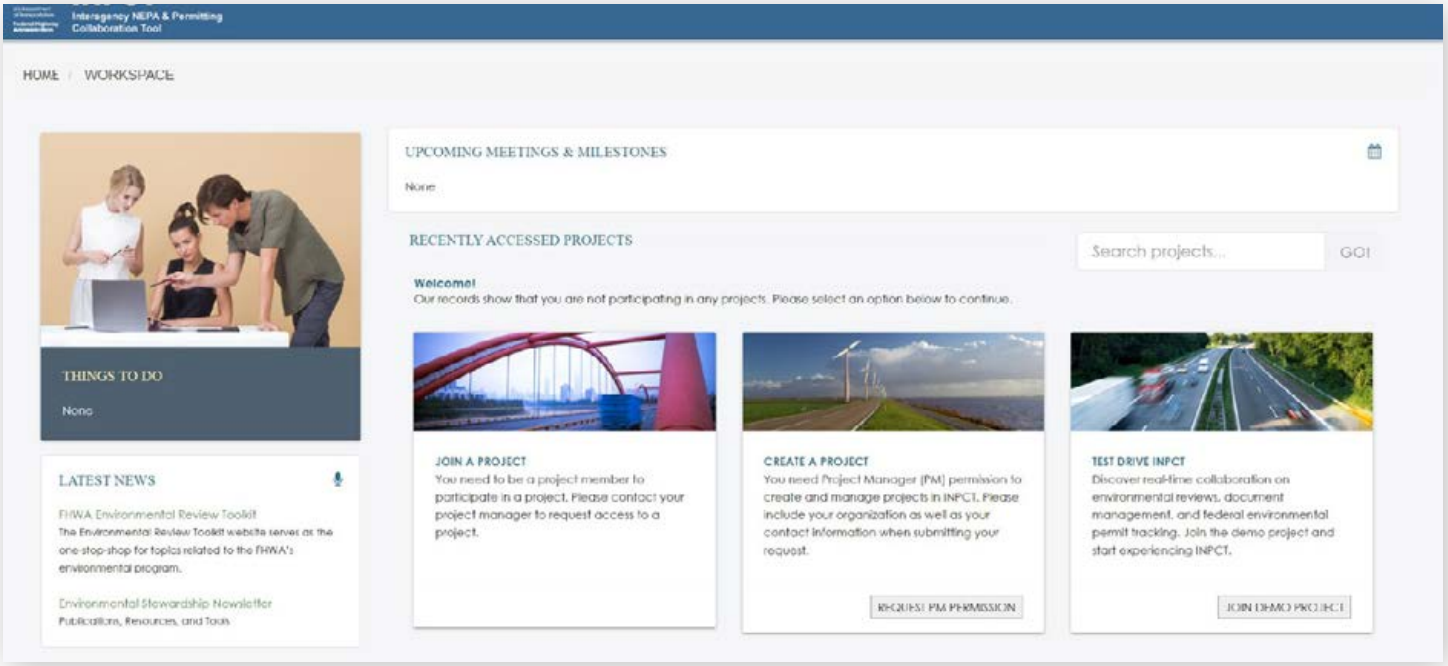
INPCT's integration with FHWA's Project and Program Action Information System means data can now be sent to the Federal Permitting Dashboard. Users only enter information once, eliminating redundant data entry. These time-saving features can help reduce the time it takes to complete environmental reviews and permit applications in line with the new regulations from the Council on Environmental Quality for implementing NEPA.

INPCT is available at *https://inpct.fhwa.dot.gov*. For more information about the tool, see FHWA's Environmental Toolkit at *www.environment.fhwa.dot.gov/pubs_resources_tools/env_tools/INPCT/default.aspx*.

MEGAN COGBURN (*Megan.Cogburn@dot.gov*) and **DAVID WILLIAMS** (*David.Williams@dot.gov*) are FHWA's INPCT system administrators.

Source: FHWA.





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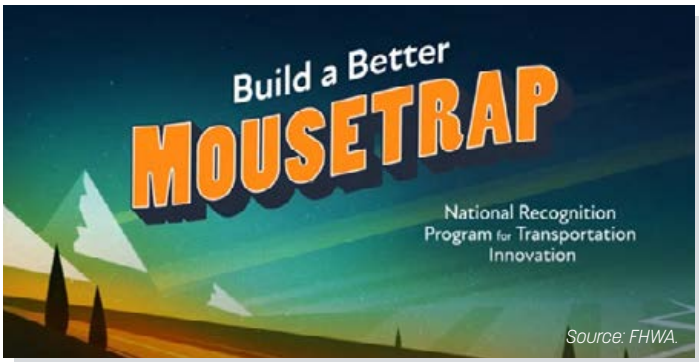


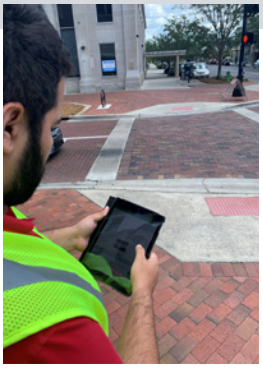
Building a Better Mousetrap Improves Communities

by **TRINETTE BALLARD**

In transportation, building a better mousetrap means solving problems by going outside the box. Each year, FHWA and Local Technical Assistance Program Centers recognize government agencies that build a better mousetrap to creatively solve problems and improve transportation in their communities. FHWA honors four organizations with 2021 Build a Better Mousetrap Awards.

Building Better Mousetraps in Local Communities

Smart Transformation Award



A mobile app increased data accessibility and improved ADA inspections.

© Seminole County, FL.

Seminole County, FL, received this year's **Smart Transformation Award**. Its developers built a mobile application to improve Americans with Disabilities Act (ADA) accessibility throughout the county. This solution reduced the county's reliance on paper, increased data accessibility, improved how ADA field inspections are conducted, and increased productivity.

Jose Salas with the Seminole County Public Works Department is proud of the solution. "We continue to discuss ways to improve the application and have received feedback for improvements from users," he says.

Innovative Project Award

FHWA named the Jones County, IA, Secondary Roads Department recipient of the 2021 **Innovative Project Award** for its development of a hopper, a dump truck attachment that saves time and money when conducting shoulder maintenance along the roadways. The hopper results in fewer materials wasted and reduced labor and equipment costs while increasing lane miles covered. The county currently has two hoppers, with a third in production.

Jones County's hopper improved shoulder maintenance.

© Jones County, IA.

"Shoulder edge dropoff is a major safety issue that our Secondary Roads Department continually mitigates with our shoulder replacement program," says Todd Postel, the Jones County assistant to the engineer.

Pioneer Award

Thermoplastic centerline markings improve visibility and safety.

© Independent Highway District.

A **Pioneer Award** recipient is among the first to solve a maintenance problem with a homegrown solution. The Independent Highway District in Sandpoint, ID, did just that by developing a new process to extend the life of centerline markings on a roadway that sees a lot of wear and tear from residents, commercial truck drivers, and heavy snowfall.

"Schweitzer Mountain Road leads to the local ski area,…receives 100 to 300 inches [254-762 centimeters] of snow annually, and has 2,000 to 5,000 vehicles traveling up and down the mountain daily," says Mel Bailey, the agency's board chair.

The district developed a process to make indentations, or divots, along the roadway's centerline using metal plates and then cover them with thermoplastic markings that can remain visible for up to 10 years. The solution saved time and money, and also improved roadway safety.

Bold Steps Award

The recipient of the 2021 **Bold Steps Award**, the Illinois Tollway, took a bold move toward improving safety. With many veteran roadway electric workers set to retire in the coming years, transportation officials needed a safer and faster way to train new electrical workers to assess, repair, and maintain the nearly 18,000 light fixtures along the 294-mile (473-kilometer) Tollway system. Traditionally, the biggest challenge was performing the training alongside high-speed traffic and in variable weather conditions while working with high-voltage equipment.

Models of roadway electrical equipment make training safer and more efficient.

© Illinois Tollway.

Roadway lighting technician Ben Pierce, who has been with the Tollway for more than 20 years, teamed up with two of his peers and gathered input from others in the agency to develop a portable training device that models the tollway's actual electrical equipment. With the device, electric workers can be trained in a safe environment more quickly and with less downtime for inoperable equipment.

Celebrating Innovative Solutions

"As always, we are excited about this year's honorees and how they are helping to transform transportation," says Joe Conway, director of FHWA's Local Aid Support team. "Recognizing innovative agencies not only shines a spotlight on the public service they provide to residents, but it also encourages other agencies to move away from the standard ways of conducting business."

For more information, visit *www.fhwa.dot.gov/clas/babm*.

TRINETTE BALLARD is an FHWA Local Aid Support Program manager in the Office of Transportation Workforce Development and Technology Deployment.

CARMA℠: Boosting Safety, Efficiency, and Reliability on the Nation's Highways

The CARMA℠ Program navigates advancements in transportation systems management and operations through emerging cooperative vehicle and infrastructure technology.

by **TAYLOR LOCHRANE**, **GOVIND VADAKPAT**, and **NICOLE PALADEAU**

As an integral piece in future safety, traffic flow, and energy improvements for the Nation's transportation system, cooperative driving automation (CDA) technology facilitates the sharing of electronic messages between vehicles and equipped roadway infrastructure. Through its CARMA℠ Program, the Federal Highway Administration advances emerging capabilities in automation and cooperation by conducting research, testing, and deployment of CDA features.

Partnerships between the Intelligent Transportation Systems Joint Program Office, Federal Transit Administration, and Federal Motor Carrier Safety Administration support the development of cooperative driving systems aimed at improving basic traffic flow to reduce recurring congestion at traffic signals, intersections, and bottleneck areas. Further details on the CARMA Program can be found in the article "CARMA℠: Driving Innovation" in the Winter 2020 issue of *Public Roads*.

The CARMA Program includes three research tracks to facilitate targeted stakeholder participation in the goals of developing, testing, simulating, and deploying CDA solutions in order to prepare for these impacts:

- Research Track 1—Traffic: Focuses on normal travel and recurring traffic conditions that result in congestion on freeways and arterials.
- Research Track 2—Reliability: Focuses on nonrecurring congestion on freeways and arterials that is caused by work zones, inclement weather, traffic incidents, and other irregular instances.
- Research Track 3—Freight: Focuses on commercial motor vehicles operating in and around port facilities.

As defined by FHWA, transportation systems management and operations (TSMO) is a set of strategies that focus on operational improvements that can maintain and even restore the performance of an existing transportation system before extra capacity is needed. CDA provides an opportunity to coordinate with TSMO operational strategies and the surface transportation system as a whole. Under the CARMA Program, several use cases

Advancements in cooperative driving automation are happening every day through FHWA's CARMA Program.

Source: FHWA.

Ongoing research and development for cooperation between vehicles and infrastructure will enhance efficiency and safety for road users.

Source: FHWA.

accounting for CDA-equipped vehicles, human-driven vehicles, equipped infrastructure, and the interactions between each are being researched.

"With innovations in CDA technology taking place every day, we are seeing that TSMO principles allow us to explore the future of our connected transportation system through the context of existing capabilities and solutions," says Faisal Saleem, manager of the Intelligent Transportation Systems Branch at the Maricopa County Department of Transportation.

Understanding the Background

All road users understand the complications posed by busy intersections, merging, and stop-and-go traffic. On the surface, these are seemingly unavoidable symptoms of a modern transportation system. But on a deeper level, these issues can increase traffic delays, escalate energy consumption and emissions, and interfere with safety. The good news is that developing technology can help address these issues. As part of an interconnected system rooted in vehicle-to-vehicle, vehicle-to-infrastructure, and infrastructure-to-vehicle communications, vehicles equipped with connected and automated driving systems have the potential to coordinate with one another and surrounding infrastructure to enhance safety, efficiency, and environmental benefits.

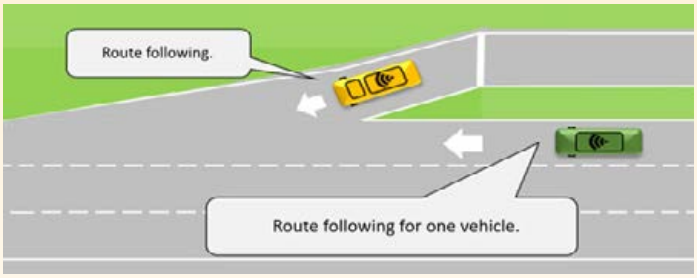
"In order to prepare for a more connected, safe, and efficient path forward, we must first understand how all of the pieces fit together," says Jennifer Toth, director and county engineer at the Maricopa County Department of Transportation. "Surrounding infrastructure is as important as the vehicles themselves because we only see success when both work together."

FHWA has developed several use cases to study the impact of CDA on TSMO strategies for basic travel.

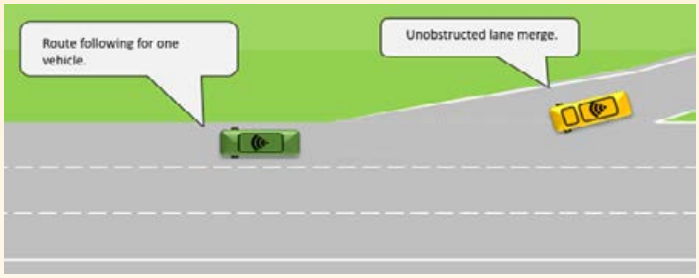
Basic Travel Use Case: Merging

Basic travel refers to recurring activities that transportation management services and traffic management centers will typically perform during normal operations when there are no incidents, special events, or other anomalies. A "notify and advise" operational action provides situational awareness to vehicles regardless of their automation level. The "merging" use case explores an automated vehicle merging onto a roadway and into the normal flow of traffic with other vehicles. Using cooperative lane change and unobstructed lane merge features on CDA-equipped vehicles, the CARMA Platform plans a smooth sideways motion from one lane into an adjacent lane, accounting for other automated and nonautomated vehicles through sensors on the vehicle.

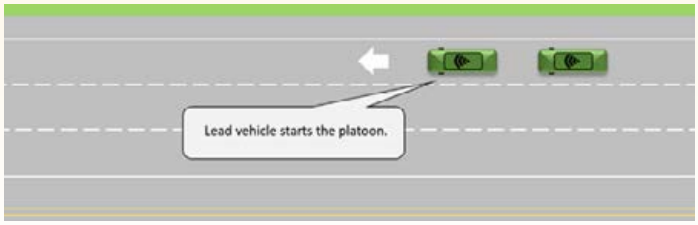
Once the merge is complete, CARMA Cloud℠ (the cloud-based, open-source software systems enabling communication and cooperation between cloud services, vehicles, infrastructure, and road users) transmits geofence messages and speed commands to the first vehicle in line, which it then shares with the rest of the vehicles to



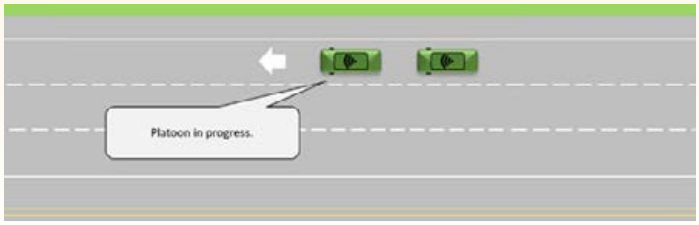
1. The vehicle begins its attempt to merge into a highway lane with another vehicle.



2. Using cooperative lane change and obstructed lane merge, the vehicle plans its entrance into the line of traffic, which uses route following to remain intact.



3. The vehicle has successfully merged onto the highway and flows with the other vehicle.



4. The first vehicle in the line (the platoon) transmits a speed advisory, which is received by rest of the vehicles.

Source: FHWA.

ensure a successful transition to the destination and the eventual termination of the line of vehicles. Through using this framework and reducing the influence of human behavior, solutions for increased highway throughput and traffic shockwave mitigation become more attainable.

CDA solutions for road weather management, traffic incident management, and work zone use cases examining several operational actions are also in development in conjunction with the basic travel use case. All of these frameworks explore distinct actions that the entity determining TSMO activities must complete in order to execute TSMO strategies.

Proof-of-Concept Testing for TSMO Use Cases

The CARMA proof-of-concept testing for TSMO use cases builds on previous research and leverages the CARMA Program ecosystem to enhance capabilities for CDA participants through four distinct arterial use cases. The aim is to reduce energy consumption and increase safety at multilane intersections. All vehicles in each use case were equipped with CDA technologies, and intersection infrastructure contained the necessary software and hardware to enable the two-way exchange, collection, and processing of electronic messages with all vehicles. CDA aims to improve the safety and flow of traffic by supporting the movement of multiple vehicles sharing the roadway in an increasingly automated future.

Simulations

Researchers conducted a series of simulations for each use case including a human-driven vehicle as the baseline and four vehicles equipped with connected and automated driving systems, representing Society of Automotive Engineers (SAE) operational classes C and D. The results showed that CDA technology reduced average fuel consumption, wait and stopping times, and delays. Additionally, the results showed that the proposed roadside components working together can accurately and efficiently control vehicle operations, coupled with the vehicle intent information. The results demonstrated that, generally, these outcomes improve as the operational class of a vehicle increases.

TSMO Use Case 1

The first TSMO use case is *basic arterial travel—stop-controlled intersections*. This use case has two main components, with the first, critical time step estimation (CTSE), designed to run on roadside equipment and the second, trajectory smoothing, on CARMA-equipped vehicles.

CTSE aims to estimate crucial points in a vehicle's journey in an intersection, such as stopping at a stop sign and accelerating through an intersection. The CTSE is determined either by the roadside equipment or by the vehicle itself, depending on its SAE operational class. Trajectory smoothing,

Society of Automotive Engineers (SAE) Operational Classes

Class	Description
No cooperative automation	No cooperation
Class A	Status sharing ("Here I am and what I see.")
Class B	Intent sharing ("This is what I plan to do.")
Class C	Agreement seeking ("Let's do this together.")
Class D	Prescriptive ("I will do as directed.")

SAE Standard J3216 explains these operational classes as they relate to SAE Standard J3016, which defines six levels of driving automation ranging from no driving automation through full driving automation.

Types of Vehicle Status in the Communication Area

1. **Entering Vehicles:** Vehicles approaching the intersection that cannot enter the intersection box in the next time step.
2. **Ready-to-Depart Vehicles:** Vehicles stopped at the stop bars or moving within the intersection box. Each is associated with a fixed order index in the ready-to-depart vehicle sequence.

   If there is more than one vehicle from an entry lane stopped at the intersection, only the leading vehicle will be considered as ready to depart and the rest will still be considered as entering vehicles.
3. **Discharging Vehicles:** Vehicles that have already departed the intersection box.

With more testing planned for the future, the CARMA Program looks forward to sharing solutions for a better road ahead.

Source: FHWA.

which aims to streamline vehicle paths, is determined by the vehicle itself.

In this use case, a vehicle enters the communication area, or intersection, joins the entering vehicle set, and begins transmitting information to roadside equipment and other vehicles. When the vehicle reaches the stop sign, it transitions to the ready-to-depart vehicle set. This transition is referred to as the stopping time, and the vehicle stores this information internally. Next, the vehicle proceeds to enter and navigate through the intersection, then exits and transitions to the discharging vehicle set, and eventually leaves the communication area entirely.

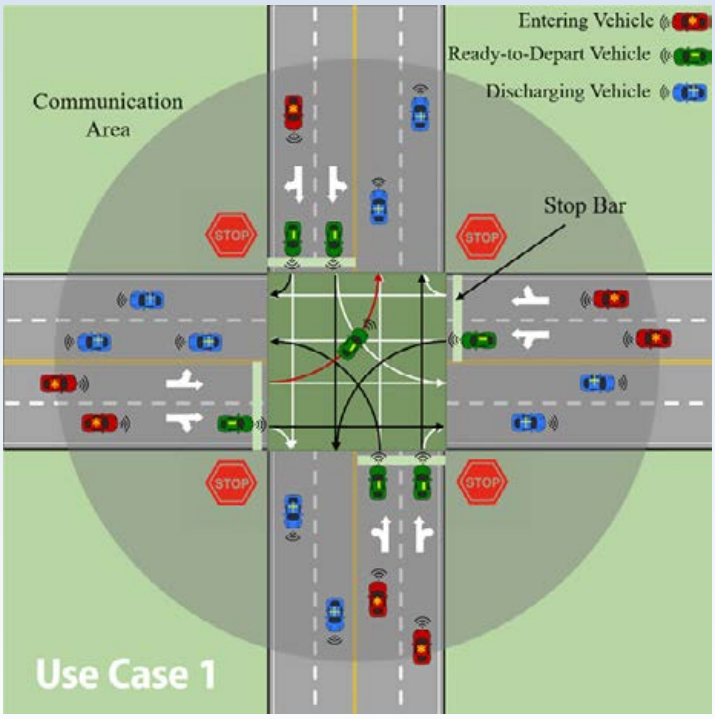
With CTSE and trajectory smoothing working together, the roadway infrastructure provides critical high-level input regarding when vehicles will perform specific actions, and enables vehicle control over trajectories and collision avoidance. The research team determined that the communication area could be expanded by adding more roadside equipment if needed to share real-time operational status (such as location and speed) and intents (such as movement group, stopping time, and entering time) among the intersection components.

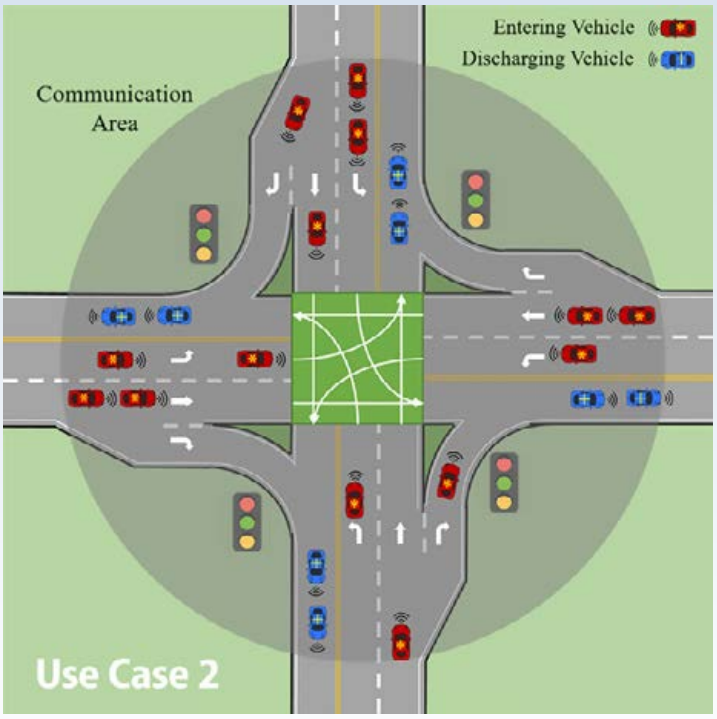
TSMO Use Case 2

The second TSMO use case is *CDA optimization at fixed-time and actuated traffic signals*. Like the first use case, this use case contains CTSE for roadside equipment and trajectory smoothing for vehicles as its main components. In this scenario, CTSE aims to estimate when a vehicle will enter an intersection, and trajectory smoothing seeks to streamline the vehicle's trajectory by estimating the time of its entrance. When a vehicle enters the communication area, it will start to transmit information to roadside equipment and other vehicles, including its desired entry time. Then, the vehicle will plan its trajectory for passing through the intersection, either at the speed limit or the highest speed safely allowed. As it travels through the intersection, it will transition from the entering vehicle group to the discharging vehicle set, and eventually leave the communication area.

TSMO Use Case 3

The third TSMO use case is *traffic signal optimization with CDA at signalized intersections*, which deals with vehicles at intersections with traffic signals. To address this, the use case added a signal optimization component that runs on a centralized roadside server to support real-time vehicle information. Upon joining the entering vehicle set and gathering information from roadside equipment and other vehicles, the vehicle will estimate its entry time to the intersection to smooth its trajectory through the intersection. This use case explores solutions such as trajectory planning and smoothing for each stage of the vehicle's journey through an intersection, including approaching an intersection with other vehicles, entering the intersection, and exiting the communication area.



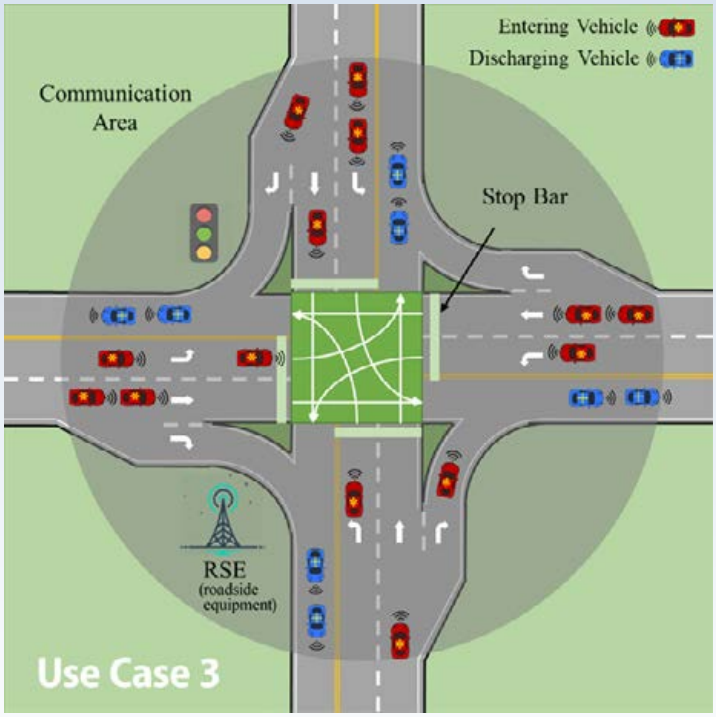


The TSMO use case testing project defines and explores four basic travel scenarios surrounding intersections.

Use Case 1 is a simple stop-controlled, four-way intersection.

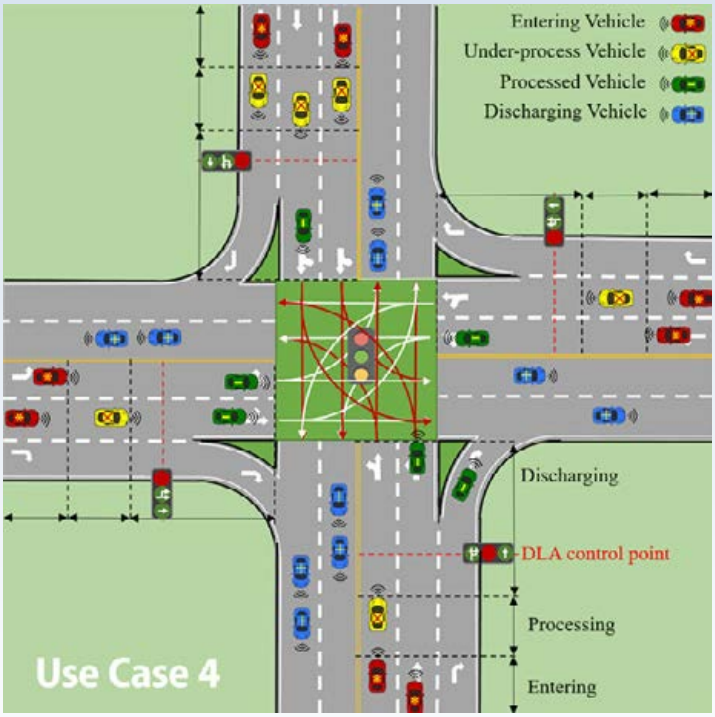
Use Case 2 is a four-way intersection controlled by fixed-time and actuated traffic signals.

Source: FHWA.



Use Case 3 involves traffic signal optimization at a signalized intersection using a cooperative control framework that runs on a centralized roadside server to support real-time vehicle information.

Source: FHWA.



Use Case 4 incorporates a signal- and lane-optimization component that employs a centralized roadside server (the DLA, or dynamic lane assignment, control point) and real-time vehicle information to assist with assigning vehicles to specific lanes. This use case primarily works to optimize the flow of each vehicle through and out of signalized intersections and generate the best signal and lane settings to increase efficiency.

TSMO Use Case 4

The fourth TSMO use case is *dynamic lane assignment along roadways with traffic signals*. Along with CTSE and trajectory smoothing, this use case incorporates a signal- and lane-optimization component that employs a centralized roadside server and real-time vehicle information to assist with assigning vehicles to specific lanes. This use case primarily works to optimize traffic flow at signalized intersections and generate the best signal timing plans and lane control to increase traffic efficiency.

The four proof-of-concept TSMO use case frameworks explore how CDA can be used to reduce operational complexity and associated risks and liabilities for traffic operators. They also distribute the computational burden among several entities, which makes the system more suitable to support real-time information. Additionally, the combination of cooperation between vehicles and between vehicles and roadside equipment can enhance the performance of the traffic system and improve the travel experiences of individual vehicles. The frameworks have the potential to reduce stop-and-go traffic and backward shockwave, increase throughput, and maintain safety for individual vehicles at stop-controlled intersections in a driverless future.

Down the Road

CDA technologies offer a wider range of possibilities for the connected transportation system than vehicles without CDA capabilities. The benefits of the ability to exchange messages with CDA-equipped vehicles offer the opportunity to enhance and improve upon current traffic control strategies. The four CDA TSMO use cases could significantly improve the traffic system and individual travel experiences, reduce stop-and-go traffic patterns, and maintain safety at conflict areas such as intersections and merge lanes.

"The world is already headed in a more connected, automated direction," says Cynthia Jones, a project manager at DriveOhio. "Now is the time to figure out how to bring all the benefits of this technology to the public in the safest possible way."

Looking ahead, the CARMA Program continues to research, test, and optimize basic travel use cases and TSMO strategies in addition to exploring use cases for cooperative perception, traffic incident management, road work management, and work zones.

"Today's research will set the foundation for a more sustainable, automated, and enjoyable transportation experience for everyone," says Raj Ponnaluri, a management engineer for the Florida Department of Transportation.

Higher levels of safety, efficiency, and reliability are on the horizon because of FHWA's research and testing for realistic scenarios.

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Nature-Based Solutions for Coastal Highway Resilience

Natural strategies for efficient, cost-effective, and ecologically friendly protection for coastal roads can help transportation agencies address the effects of extreme weather events.

by **KATHERINE BUCKINGHAM** and **JESSICA TOROSSIAN**

As the climate continues to change, extreme weather events—such as damaging coastal storms, drought, and extreme heat and precipitation—are expected to increase in frequency. According to the U.S. Global Change Research Program's *Fourth National Climate Assessment* report, in the United States, there are more than 60,000 miles (97,000 kilometers) of roads and bridges in coastal floodplains and more than $1 trillion in coastal property that may be at risk from these effects of climate change.

Developing a network of resilient coastal roads is a priority for the Federal Highway Administration in order to ensure the safe passage of the American public on coastal roads and to maximize coastal investments. While several nature-based solutions have the ability to innately adapt to rising sea levels, traditional strategies to protect coastal infrastructure that rely on hardening shorelines and other "gray" solutions may not be adaptable or must be specifically designed to do so, which can be costly. These solutions can also have unintended consequences, such as increased erosion or deposition, along other parts of the coastline.

Nature-based solutions that rely on existing or enhanced landscapes help improve roadway resiliency by reducing impacts to coastal roads from hazards such as rising sea level, storm surge, and "nuisance" flooding (such as high tide or windblown flooding). Often these "green" strategies are both more effective and less costly than traditional engineering or gray solutions on their own.

"More States and municipalities are turning to nature-based solutions to protect coastal highways and improve the environment while providing a natural aesthetic and other benefits to coastal communities," says Elizabeth Habic, an environmental protection specialist with the FHWA Office of Natural Environment.

Considerations for Deploying Nature-Based Solutions

The term "nature-based solutions" refers to the use of natural materials and processes to reduce erosion, wave damage, and flood risks to coastal infrastructure. These solutions can be used instead of, or in conjunction with, traditional gray methods of shoreline stabilization and protection techniques. Nature-based solutions include the use of naturally occurring features, as

Nature-based solutions can offer coastal roads protection from the effects of rising sea levels and extreme weather events.

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well as nature-based features that are created or enhanced by human design, engineering, and construction.

In many coastal areas, naturally occurring habitats and geographic features can provide protection from the coastal processes and storm events that threaten coastal roads. The main habitats involved in nature-based solutions are tidal salt marshes, mangroves, maritime forests, coral and shellfish reefs, beaches, and dunes. In addition to buffering storm effects, these habitats also provide other community benefits (called ecosystem services) related to recreation, water quality, local fisheries, and climate change mitigation.

State and local transportation agencies can capitalize on these ecosystem services—and even enhance them—by deploying nature-based solutions in strategic ways that can use one particular intervention or layer multiple solutions to be as simple or complex as needed. The type of solution that a transportation or planning agency chooses to deploy will be location specific and highly dependent on local geography and ecology as well as the type, frequency, and severity of coastal impacts to road infrastructure. Additionally, each solution may have unique permitting and right-of-way requirements. Successful design and implementation of nature-based solutions often require input from a cross section of expertise, including transportation professionals, coastal engineers, and environmental scientists.

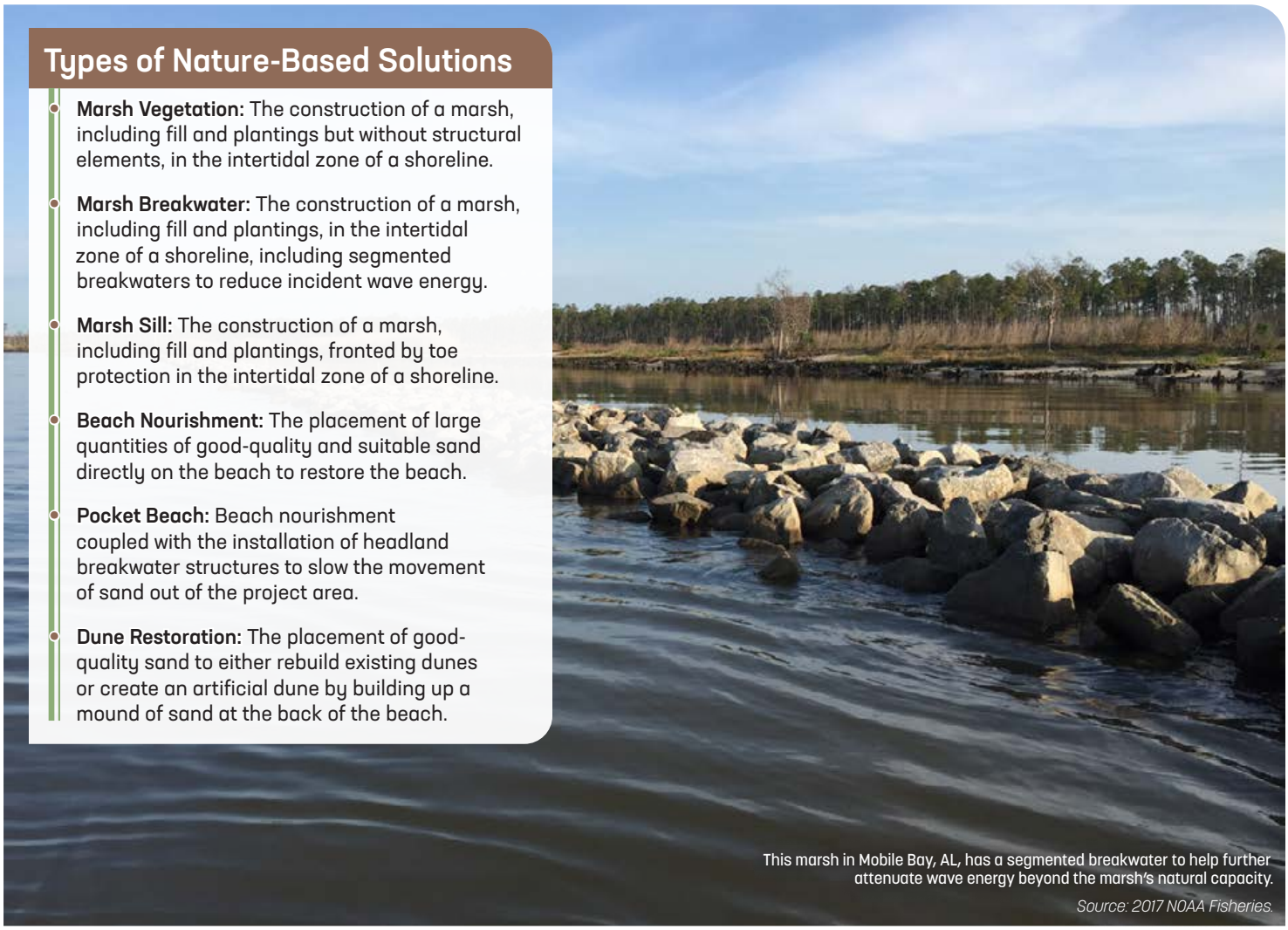
Salt Marshes

There are three common solutions that can be deployed in regions where salt marshes are common: marsh vegetation, marsh sill, and marsh breakwater. Solutions that use salt marshes generally provide a medium level of protection against both increased wave energy (because of the structure of marsh vegetation) and erosion (because root systems hold soil in place). They also deliver some protection against coastal flooding and are more natural and aesthetically attractive for the community. Marsh-based solutions offer strong environmental benefits because salt marshes provide a variety of ecosystem services, including improving water quality and providing habitat and nurseries for a variety of species. Salt marshes also play an important role in denitrification and help trap atmospheric carbon.

Despite these benefits, there are several challenges associated with deploying marsh-based solutions. Marsh plants can require maintenance, especially during the early stages of life. Project funding should include costs for the removal of dead plants and debris from the marsh and the planting of new vegetation as needed. While the success of these projects is well documented, service life can be hard to predict because a marsh-based solution can be highly dependent on elevation and marsh slope. Tidal elevation may change as sea levels rise and marsh slope and local water conditions can heavily influence shoreline changes. While salt marshes can naturally adapt to many of these changing conditions, in some locations, additional efforts to mitigate for sea level rise and high levels of runoff can help ensure an effective design.

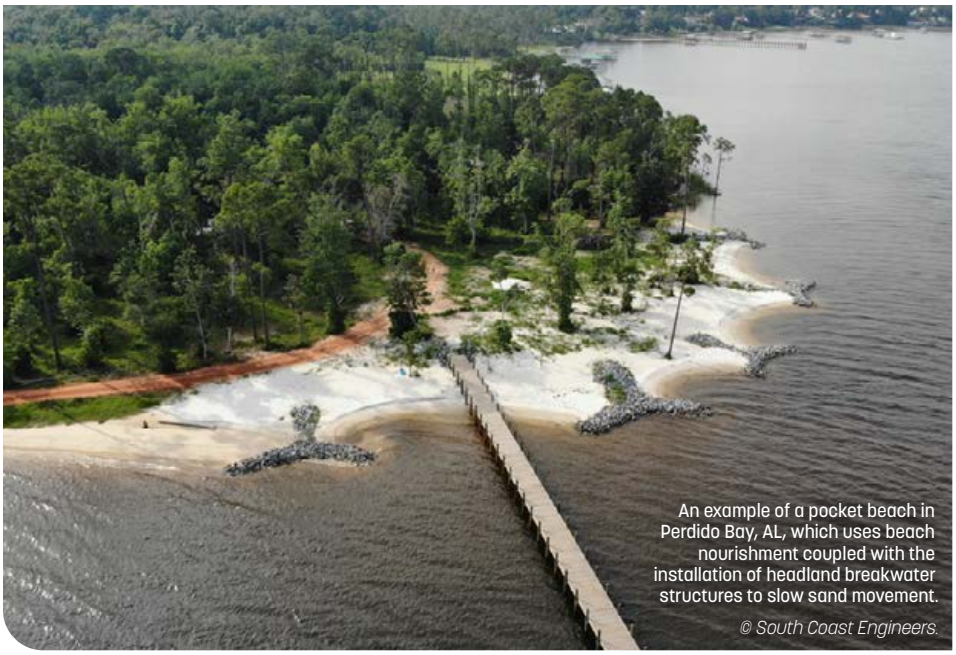
Types of Nature-Based Solutions

- **Marsh Vegetation:** The construction of a marsh, including fill and plantings but without structural elements, in the intertidal zone of a shoreline.
- **Marsh Breakwater:** The construction of a marsh, including fill and plantings, in the intertidal zone of a shoreline, including segmented breakwaters to reduce incident wave energy.
- **Marsh Sill:** The construction of a marsh, including fill and plantings, fronted by toe protection in the intertidal zone of a shoreline.
- **Beach Nourishment:** The placement of large quantities of good-quality and suitable sand directly on the beach to restore the beach.
- **Pocket Beach:** Beach nourishment coupled with the installation of headland breakwater structures to slow the movement of sand out of the project area.
- **Dune Restoration:** The placement of good-quality sand to either rebuild existing dunes or create an artificial dune by building up a mound of sand at the back of the beach.



This marsh in Mobile Bay, AL, has a segmented breakwater to help further attenuate wave energy beyond the marsh's natural capacity.

Source: 2017 NOAA Fisheries.



An example of a pocket beach in Perdido Bay, AL, which uses beach nourishment coupled with the installation of headland breakwater structures to slow sand movement.

© South Coast Engineers.

Beaches and Dunes

In areas where beaches or dunes are prevalent, agencies can deploy solutions such as pocket beach creation, beach nourishment, and dune restoration. All three solutions are highly effective at protecting upland resources during storms, while pocket beach and beach nourishment solutions are also beneficial for reducing erosion. Beach-based solutions offer additional habitat for seabirds and other beach-going animals like sea turtles, and deliver added community benefits for local property owners, tourists, and recreational users.

For all three strategies, sand is sourced from a borrow-area located either offshore or from a coastal dredging project or upland sandpit. Sand should have an appropriate grain size that matches the native beach sand. Sourcing high-quality sand can create a challenge as source sand may impact historic and cultural resources or artifacts that should be avoided. Imported sand should be cleared of nonnative species that could potentially be introduced to a new area.

Dune restoration is often coupled with the planting of native vegetation, which may need to be maintained. Design life can be dependent on local conditions and renourishment may be required to maintain the beach or dune. Pocket beaches face the additional challenge of sizing and siting the headland structures, but the addition of these structures can increase the design life almost indefinitely.

Hybrid Solutions

In certain areas where wave energy may be particularly challenging to dissipate or local conditions lead to more flooding, it may be best to employ a hybrid approach that combines a nature-based strategy with gray infrastructure solutions to provide more robust protection. Hybrid solutions may also be best for other habitats such as mangroves, maritime forests, and intertidal and subtidal reefs.

Mangroves can act in a similar way to marshes by attenuating wave energy and preventing erosion from complex root structures. Upland forests can also be useful in protecting coastal infrastructure, but they can take quite some time to grow into a protective barrier. For this reason, efforts to conserve maritime forests are often more successful than re-planting or encouraging new growth. Nearshore shellfish reefs and coral reefs can help attenuate wave energy but do not provide much protection against any coastal flooding that is not wave induced.

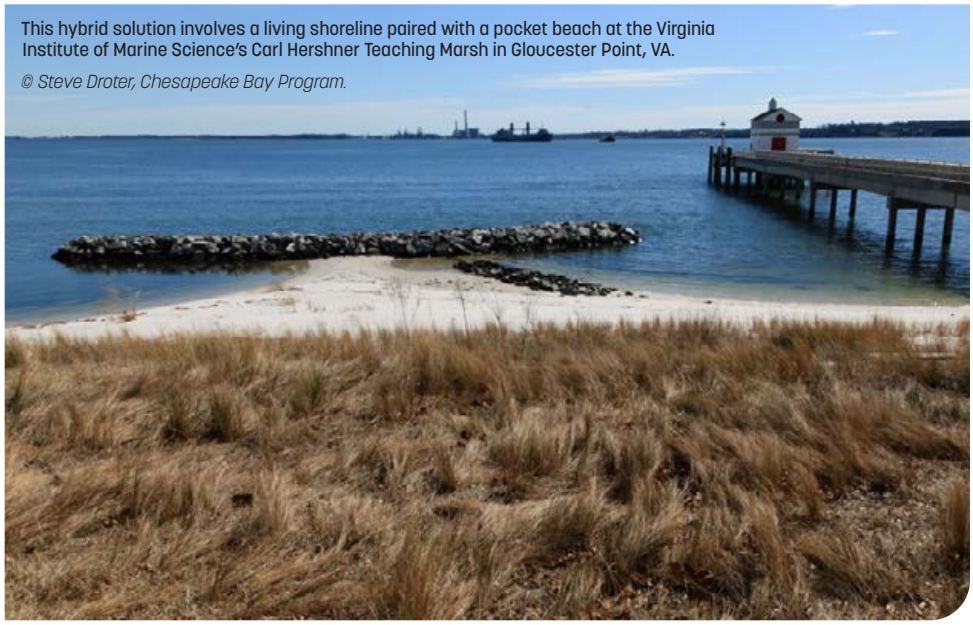
Hybrid solutions can include:

- Constructed marshes with stone or timber sills
- Marsh/mangroves with breakwaters, reefs, or habitat devices
- Beach nourishment with breakwaters and/or groins
- Constructed dunes with reinforced cores

Corpus Christi's Resilience Pilot Program

Laguna Shores Road is a major thoroughfare in the Flour Bluff neighborhood of Corpus Christi, TX. Currently, several locations along Laguna Shores Road are subject to periodic flooding under spring tide and other typical (nonstorm) conditions. Shoreline erosion has also undermined the roadway in multiple locations. The southern end of the project is particularly vulnerable to extreme weather because there is no habitat buffer between the roadway and the open water of the Laguna Madre. These sites are especially susceptible to the impacts of storm surge and extreme weather events, and this vulnerability will increase in the face of sea level rise.

As part of an applied research deployment, the Corpus Christi Metropolitan Planning Organization (Corpus Christi MPO) received $110,770 from FHWA to support the design of an innovative, nature-based shoreline protection feature to enhance resilience to extreme weather. The city of Corpus Christi is currently initiating the design phase of a project to rebuild three separate portions of Laguna Shores Road to improve level of service and reduce susceptibility to inundation.



This hybrid solution involves a living shoreline paired with a pocket beach at the Virginia Institute of Marine Science's Carl Hershner Teaching Marsh in Gloucester Point, VA.

© Steve Droter, Chesapeake Bay Program.

A pilot project in Corpus Christi, TX, aims to improve the resilience of Laguna Shores Road, shown here under typical (nonstorm) conditions, to extreme weather events.

© Corpus Christi MPO.

The Corpus Christi MPO conducted an alternatives analysis to assess the living shoreline. A multidisciplinary consultant team gathered data and conducted a metocean analysis. Metocean conditions refer to the combined wind, wave, and climate conditions found at a certain location, and may include measurements and statistics such as air temperature, humidity, wind speeds, water level fluctuations, bathymetry, salinity, and stratification. The team also conducted a site visit and habitat assessment, hydrographic surveying, and preliminary geotechnical testing.

The team developed two breakwater concepts, a riprap breakwater and a reef ball breakwater, to provide wave protection to Laguna Shores Road and to support hard substrate habitat. The crew also developed a marsh fill concept to provide additional habitat and living shoreline benefits. They designed both the breakwater concepts and the marsh fill concepts to be constructed with equipment typical for roadway construction and without additional specialized equipment.

The next step was constructing the pilot shoreline protection project as part of the roadway reconstruction project and monitoring effectiveness in terms of habitat development and shoreline condition. The monitoring will help the agency to evaluate the utility of the pilot techniques to enhance the durability of other segments of Laguna Shores Road and other similarly vulnerable transportation infrastructure.

"This pilot project has been and will continue to be a collaborative effort of all the partners," says Robert MacDonald, PE, MPA, the transportation planning director for the Corpus Christi MPO. "The MPO managed an interdisciplinary team of specialized experts from the academic, environmental nonprofit, municipal, and private sectors. This effort provides a real-world example of combining the elements of resiliency with a planned roadway reconstruction project."

A Pocket Beach in Perdido Bay, AL

In Perdido Bay, AL, a single homeowner created a pocket beach in 2018 between two timber and sheet-pile bulkheads to restore a beach on a stretch of shoreline that is heavily armored by individual bulkheads. The two bulkheads act as headland structures, separating the beach from the adjacent coastline and creating the pocket beach—a type of isolated littoral cell. Neighboring bulkheads were used as the landward anchor points for the headland structures.

At a final cost of $40,000, the project generated multiple benefits. One is that the beach fill provides additional habitat for shorebirds and sea turtles. The structural elements attenuate waves and improve the stability of the beach, which can also decrease waves during storm events for upland resources. As a small, homeowner-level project on private land, the responsibility falls on the homeowner to maintain the beach going forward, and the largest challenge will be ensuring that the beach will be monitored in the future.

Beach Nourishment in Dauphin Island, AL

In 2016, the town of Dauphin Island, AL, completed the Dauphin Island East End Beach and Barrier Island Restoration Project to prevent erosion and protect upland ecosystems and infrastructure in coastal Alabama. The project involved the placement of 320,000 cubic yards (240,000 cubic meters) of sand on an eroding beach that protects a maritime forest, freshwater lake, and substantial upland infrastructure. The $6.7 million project required an extensive, detailed survey of cultural resources in an offshore borrow area. The project also involved the interaction of State law and Federal policy because of a U.S. Coast Guard facility within the project limits. The beach nourishment included rehabilitating existing, detached rock groins perpendicular to the shore and converting them into breakwater headlands, which mitigates ongoing erosion. The project has successfully endured several tropical storms and hurricanes.

A major challenge was that the initial project grant funding was inadequate to cover all project costs. Fortunately, the town of Dauphin Island secured additional grant funding to cover the shortfall without compromising project design. The benefits of this project include increased property value, recreation, tourism, and habitat. The restored beach provides habitat to a variety of species, such as nesting habitats for shorebirds and sea turtles.

Creative Dune Solutions for Maximum Protection in Saco, ME

Relatively high beach and dune erosion—approximately 3 feet (1 meter) per year—prompted the Ferry Beach Park Association in Saco, ME, to undertake a dune restoration project to protect roads and homes from flooding and erosion. Given the high erosion rate, the organization constructed an 800-foot-long (240-meter-long) secondary dune ridge landward of the existing dune crest and 1 foot (0.3 meter) above the effective 100-year base flood elevation determined by the Federal Emergency Management Agency. This approach helps protect upland resources from floods and waves during storms, enables native vegetation to grow, and provides additional dry sand habitat. Volunteers also planted native American beachgrass (*Ammophila breviligulata*) and installed fencing to help trap sand in the constructed dune.

The agency completed the project by the spring of 2009 at a final cost of $29,000. The benefit of this project is that the added sediment from dune restoration supports the protective capacity of the entire beach system (dune, beach, and nearshore area). Any sand eroded from the dune during a storm supplies a reservoir of sand to the fronting beach and nearshore area. Sand

dunes provide a unique wildlife habitat, and dunes also act as a barrier to storm surges and flooding, protecting landward coastal resources and reducing overwash events.

FHWA's Implementation Guide

Implementing projects like these examples can help individuals and organizations address and mitigate the effects of climate change. To help, FHWA is producing research and offering technical assistance to enable transportation agencies to use natural and nature-based features to improve the resilience of transportation systems.

In addition to sponsoring pilot projects to assess the potential for nature-based techniques to protect specific locations along coastal roads and bridges, FHWA developed *Nature-Based Solutions for Coastal Highway Resilience: An Implementation Guide* (FHWA-HEP-19-042) to help transportation professionals understand when, where, and which nature-based solutions may work for them. The guide is available at *www.fhwa.dot.gov/environment/sustainability/resilience/ongoing_and_current_research/green_infrastructure/implementation_guide*.

The majority of the guide is organized around how nature-based solutions can be developed through the transportation project delivery process. The document provides guidance on how to consider nature-based solutions in the planning process and how to conduct a site assessment to determine whether nature-based solutions are appropriate. It also describes key engineering and ecological design considerations, permitting approaches, construction considerations, and monitoring and maintenance strategies.

FHWA's *Hydraulic Engineering Circular No. 25: Highways in the Coastal Environment, 3rd Edition* (FHWA-HIF-19-059) also provides information on the planning and design of nature-based solutions for use on highways and bridges in coastal environments. HEC-25 is available at *www.fhwa.dot.gov/engineering/hydraulics/pubs/hif19059.pdf*.

FHWA's Elizabeth Habic says, "Working with nature and incorporating nature-based solutions into transportation projects is a proven and effective way to develop resilient infrastructure while simultaneously enhancing the surrounding environment with benefits to local ecosystems, residents, tourism, and recreation."

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JESSICA TOROSSIAN is an operations research analyst at the Volpe Center National Transportation Systems Center. She holds a Ph.D. in ecology, evolution, and marine biology from Northeastern University.

For more information, see *www.fhwa.dot.gov/environment/sustainability/resilience/ongoing_and_current_research/green_infrastructure/index.cfm* or contact Elizabeth Habic, an environmental protection specialist in FHWA's Office of Natural Environment, at *elizabeth.habic@dot.gov*.

FHWA's implementation guide provides transportation practitioners with step-by-step recommendations for integrating green infrastructure for coastal resilience.

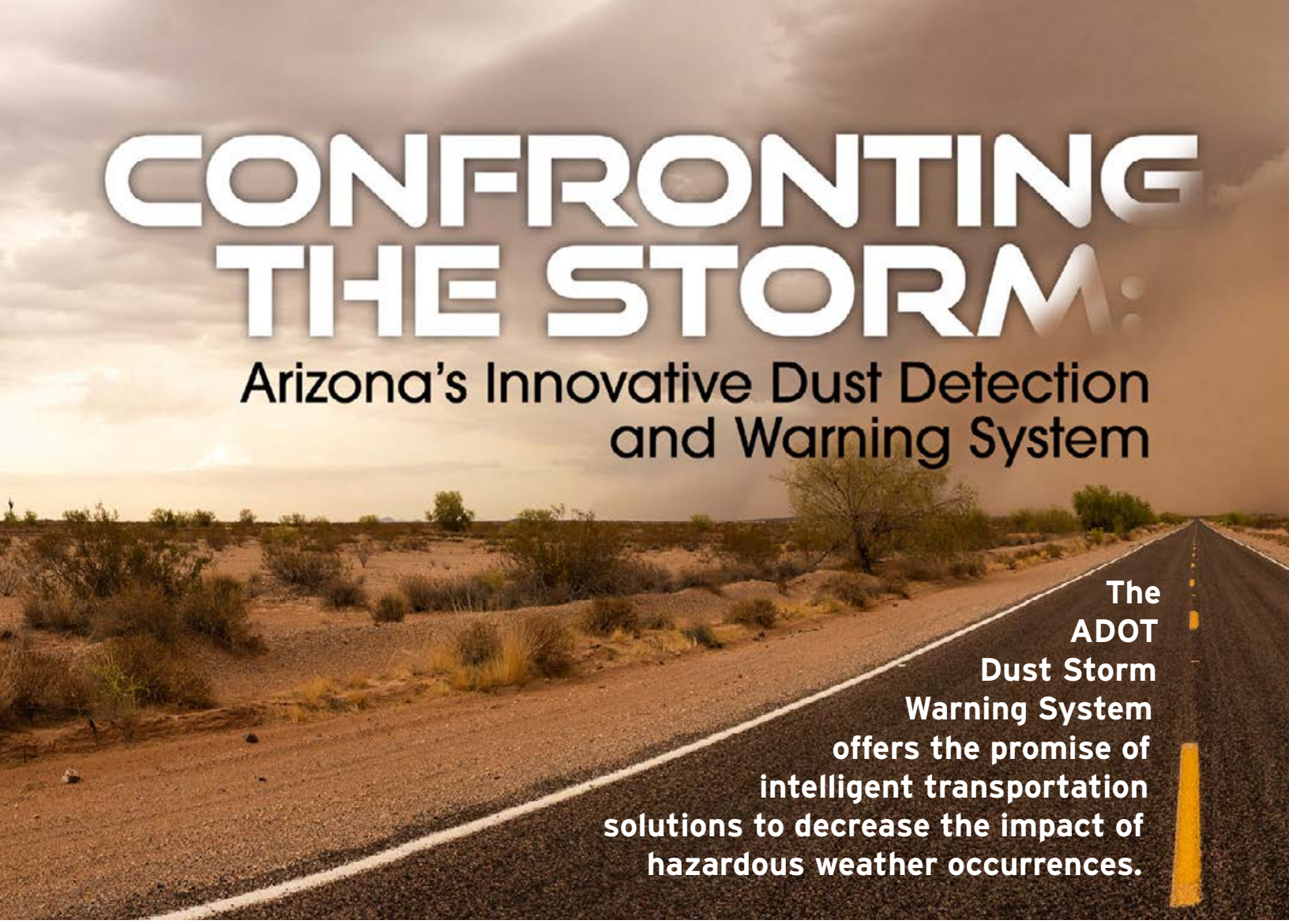
Source: FHWA.

The town of Dauphin Island, AL, undertook a beach nourishment project in 2016 to prevent erosion and protect upland ecosystems and infrastructure in coastal Alabama through the placement of 320,000 cubic yards (240,000 cubic meters) of sand on an eroding beach.

© Sam St John, FlyTheCoast.com.

CONFRONTING THE STORM:

Arizona's Innovative Dust Detection and Warning System



The ADOT Dust Storm Warning System offers the promise of intelligent transportation solutions to decrease the impact of hazardous weather occurrences.

by **TONY COVENTRY** and **KEVIN DUBY**

Innovations to boost safety on U.S. roadways may look different depending on the region. In some parts of the southwest United States, factors like climate change, land use, farming practices, and desert environments have combined to create a serious problem—major dust storms that can block visibility for miles and make driving unsafe.

In the desert regions of Arizona, factors like these have increased the severity and number of dust storms, which can emerge as a side effect of thunderstorms. Thunderstorms frequently produce downbursts and straight line winds, which can blow loose sand and dirt from the ground, causing a large wall of dust and debris, or a dust storm, to form. These dust storms, sometimes called "haboobs," are unpredictable and unexpected and can reduce visibility to near zero in seconds, resulting in deadly multivehicle crashes on roadways. The National Weather Service's research finds that dust storms are the third deadliest weather event in Arizona. According to its report, 157 people died and 1,324 were injured in 1,521 "dust incidents" on Arizona highways between 1955 and 2011. Since 2000, dust has contributed to 1,207 collisions resulting in 40 fatalities and 1,136 injuries.

In order to address this issue and mitigate the impact of dust storms, the Arizona Department of Transportation (ADOT) developed a state-of-the-art, fully automated dust storm detection and warning system along a critical 10-mile (16-kilometer) segment of I–10 between Tucson and Phoenix—an area prone to sudden blowing dust events. The system uses multiple intelligent transportation system technologies to detect events, warn drivers, and modify driver behavior using a dynamic variable speed limit system and dynamic message signs. The primary objective is to enhance safety and driver awareness during blowing dust events.

This solution is an excellent example of a weather-responsive management strategy (WRMS). WRMS is a Federal Highway Administration initiative focused on deploying methods to mitigate the impact of weather on the transportation system.

"One of the primary benefits of developing WRMS is that those strategies can be used for a myriad of weather events, including dust storms and low-visibility issues, that impact our roadways and public safety," says David Johnson, the team leader for the FHWA Road Weather Management Program. "ADOT's dust detection system offers a perfect example of a regional approach to mitigate weather impacts through WRMS."

The ADOT Dust Warning System

ADOT installed 13 sensors—12 that measure visibility and 1 that measures both visibility and precipitation—in strategic locations on I–10 from milepost 209 to 219. The instruments are installed 8 feet (2.4 meters) off the ground to record the quality of visibility that

Dust storms can rapidly drop driver visibility to almost nothing. The Arizona Department of Transportation (ADOT) is piloting a system to detect dust events and warn motorists.

ADOT installed radar on light poles along a section of I–10 to help spot dust events.

drivers are experiencing. Placed about a mile (1.5 kilometers) apart, the spacing gets tighter closer to milepost 214, which is used as the center, or ground zero, for the system. The instruments measure the number of particles in the air and then calculate the visibility in feet.

"We chose these sensors because we have used them in the past; they are reliable and easy to maintain and calibrate," says David Locher, P.E., ADOT's manager for Transportation Systems Management and Operations (TSMO) Systems Maintenance.

In addition to the ground sensors, the system also uses an X-band (between 8.0 and 12.0 gigahertz) radar with a 60-mile (97-kilometer) radius. During the project design phase, ADOT discovered that the two major weather radars nearby, one in Phoenix and one in Tucson, did not sufficiently detect the area of concern. The two existing radars could determine high-rising thunderstorms but could not spot dust events closer to the ground. To complement the real-time ground observations the visibility sensors provide during an event, ADOT installed X-band radar near the new intersection of SR–87 and I–10. This system provides advance notice and warning of approaching storms.

The radar, the first and only to be owned by a State DOT, has the capability to rotate 360 degrees, and the current scanning pattern is designed to see both rain and dust. With each rotation, the radar increases one degree in elevation, starting at 0.5 degrees and going up to 5.5 degrees. The change in elevation enables ADOT to create 3-D images of a storm within a 60-mile radius.

Leveraging the FHWA Road Weather Management Pathfinder program, ADOT can also send the radar imagery directly to the National Weather Service, where this data could be used in research and development to potentially better forecast sandstorms in the future.

A roadside sign alerts motorists to the variable speed limit corridor that is part of the dust detection system on I-10 between Phoenix and Tucson.

© ADOT.

Adjusting Speed Limits for Safety

The system also contains a variable speed limit component, which includes a series of programmable speed limit signs that can display changes to the legal speed limit from a maximum of 75 miles (120 kilometers) per hour to as low as 35 miles (56 kilometers) per hour. Eight of these units are tightly spaced, around 1,000 feet (300 meters) apart, on the I–10 corridor, four on the eastbound side at milepost 209 and four on the westbound side at milepost 219. Additional variable speed limit signs lie at 2-mile (3-kilometer) intervals approaching the corridor. As the sensors begin to measure a reduction in visibility, the data (visibility measured in feet) are analyzed and, when appropriate, messages are sent to the system to reduce the speed limit in increments.

Locher explains further: "For example, if the visibility sensors record a visibility between 900 and 1,200 feet [270 and 370 meters], we have designed the system to automatically lower the speed limit to 45 miles [72 kilometers] per hour for that degree of visibility. We did not want drivers to see a speed limit sign go from 75 to 45 miles [120 to 72 kilometers] instantly, so we designed the series of four close-spaced signs. The four consecutive signs may [indicate] 65, 65, 65, 65; then 30 seconds later, 65, 55, 55, 55; then another 30 seconds, 65, 55, 45, 45. If we need to reduce to 35, it takes a total of 2 minutes to do the steps."

The system goes back to its normal status of 75 miles (120 kilometers) per hour in a 5-minute interval. The slower return is intended to make sure the dust event is over.

In addition to warning motorists of conditions using variable speed limit messaging, ADOT installed four new dynamic message signs within the corridor and uses existing ones outside the corridor. The signs, or "boards," are preprogrammed with messages that automatically change, depending on the sensed conditions, to prepare motorists for the expected conditions they will experience.

ADOT's Traffic Operations Center can monitor the health of the system and measure the impact it has on driver behavior through additional system components. Embedded loop sensors in the pavement measure and report traffic speed and volume. The data can be used to measure the change in driver behavior and response to the changing speed limit. Six CCTV

ADOT's Traffic Operations Center can receive CCTV images, like this one of dust storms along I-10.

© ADOT.

cameras can be accessed by the center to monitor both the health of the system and dust events.

The radar provides advance warnings while sensors measure visibility. When the visibility goes down, the system reduces the speed limit and populates the dynamic signs with messages indicating the severity of the dust event.

"All of it can be monitored and managed by the Traffic Operations Center, but almost everything is fully automated, hands free," says Locher.

Overcoming Design Challenges

ADOT hired a firm to design the system in 2016 and added it to a widening project that broke ground in December 2017. The system used crash data from 2010 to 2015 to identify the most effective location for deployment. While building the system, ADOT ran into several challenges. Any system like this requires solid communications, and the quality of the available communications at the device locations often wasn't optimal. Integrating multiple devices from multiple vendors also proved to be demanding, but the project overcame this obstacle with consistent communication and a collaborative approach with the contributors. Finally, designing and implementing the algorithms that determined what speeds the variable signs should be changed to relative to what observation analytics were available was difficult. However, the system design includes flexibility and scalability so that as it grows and evolves, these algorithms and analytics can be modified and become even more effective. The system, including the X-band radar, cost $6 million; it was completed and operational in the summer of 2020.

The Dust Warning System is still operationally new, and the monsoon season following its debut produced fewer than average events, making initial evaluation of its functionality difficult to determine. Even so, the system has garnered attention and accolades, including a nomination for an American Association of State Highway and Transportation Officials Operational Excellence award. In addition, the National Weather Service has named ADOT a 2020 Weather Ready Nation Ambassador of Excellence for the agency's work on this project and others.

Looking to the Future

As transportation-related technologies continue to advance, new challenges related to the effects of climate change and other related issues will arise and need to be addressed. For example, the increased deployment of connected and autonomous vehicle technology will require intelligent transportation system solutions to provide real-time, relevant information to equip vehicles to lessen the impact from weather events. Weather-responsive management solutions will continue to be a cornerstone to meeting those challenges. The ADOT Dust Warning System is the perfect combination of proactive, collaborative, and forward-thinking development and deployment of new sustainable technologies, solutions, and strategies that create systemic resiliency.

TONY COVENTRY is a transportation specialist with FHWA's Road Weather Management Program. His current focus area is developing climate change impact mitigation and resiliency strategies for the Nation's surface transportation system.

KEVIN DUBY is the statewide road weather manager for ADOT, coordinating the road weather information system networks and supporting winter operations. He has been with ADOT since 2002. He holds a master's degree in emergency management from Arizona State University.

For more information, contact Kevin Duby at *kduby@azdot.gov*.

New technologies, like Arizona's Dust Warning System, can help address weather-related challenges from the effects of climate change and other issues.

SAFETY on ICE

Ice roads are critical to seasonal transportation in the North. FHWA and its partners are working to improve safety and establish uniform standards for their design, construction, operation, and use.

by **ADAM LARSEN** and **BILLY CONNOR**

Frozen rivers and lakes provide natural, relatively smooth trails for walking and pulling sledges. As a result, they have served as important transportation corridors for thousands of years in the circumpolar north.

The sled dog originated in Russia several thousand years ago and eventually came into use in North America. Because dogs pulling sleds move much more quickly than a person on foot, the dogs and their owners could fall through thin ice before they have time to see it. Luckily, stories abound concerning the innate ability of dogs to sense and avoid thin ice, thus cementing a strong bond between the handler and the dogs.

While the modern snowmobile was patented in 1916, it did not become popular until the 1960s with the introduction of lightweight frames. These speedy, highly maneuverable machines rapidly replaced the sled dog. Traveling at speeds that exceed 100 miles (160 kilometers) per hour, riders could find themselves on thin ice before they could take evasive action. Riders rely on word of mouth and an intimate knowledge of local rivers to avoid danger, because few of the rivers offer markings that identify safe routes. Consequently, fatalities occur every winter as unwary travelers fall through the ice.

More recently, ice roads have carried passenger vehicles as well as heavy freight vehicles. As the weight of the vehicles increases, the danger of falling through the ice also increases. Vehicle recovery also becomes increasingly difficult.

The effects of climate change and shifts in weather patterns have also impacted ice roads. Shorter ice road "seasons" and warm mid-winter storms can make ice roads even more hazardous. These challenges will require more frequent inspections of ice thickness during and after winter storms, and may limit the length of the ice roads that can be built and maintained.

Despite these dangers, ice roads continue to be a common transportation corridor in the north. They provide an efficient means of moving supplies, equipment, people, and resources such as gravel between communities and commercial operations that are inaccessible by roads. For example, the ice road on the Kuskokwim River enables freight to be distributed from Bethel, AK, to surrounding villages at a cost significantly lower than that of moving freight solely by air.

To maintain ice roads, like this one near Bethel, AK, crews must clear snow and check for hazards like cracks and thin ice.

Ice roads are essential to local accessibility in Alaska and other northern regions, but present challenges in establishing and maintaining them safely and efficiently. Here, the ice road created on the frozen Kuskokwim River in Alaska is seen from the air.

Source: FHWA.

An example of the increased use of ice roads is the river crossing at Tanana, AK, which connects a newly constructed road on the south side of the Yukon River to the village of Tanana on the north side. The ice road connects Tanana to the rest of the Alaskan highway network, reducing the cost of freight coming into the community.

To address the challenges of safely using and maintaining ice roads, the Federal Highway Administration's Office of Tribal Transportation hosted a peer exchange and initiated an ice road research project with the University of Alaska Fairbanks to develop a guide for establishing and maintaining ice roads.

Ice Road Peer Exchange

In March 2020, FHWA's Office of Tribal Transportation, the Bureau of Indian Affairs, and the Center for Safety Equity in Transportation at the University of Alaska Fairbanks facilitated a peer exchange on ice roads. The discussion brought together representatives from 17 Tribes from southwest Alaska and centered around the construction, operation, and benefits of ice roads.

One speaker at the meeting was Mark Leary, the director of development and operations for the Native Village of Napaimute in Alaska, who leads the annual effort to clear the frozen Kuskokwim River and create the ice road. In most years, Leary and his crew can establish an average of 200 miles (320 kilometers) of ice road. In 2020, they set a record by clearing and maintaining the river from Tuntutuliak to Sleetmute, a distance of about 355 miles (571 kilometers). Communities along the ice road provide what assistance they can, including fuel, equipment, lodging, and manpower.

Attendees of the peer review listened raptly as Mr. Leary described his experiences in the construction of the ice road. "With few resources and little time, he and his team accomplished a near miracle," says FHWA's Todd Brockmann. "Even more impressive, Mr. Leary drew on his knowledge of the river and what he learned from the literature published by the Canadian ice road operators and talking to others."

The longer ice road caused an immediate impact on the villages it served. Air freight flown into the main airport at the hub city of Bethel on large aircraft could be ferried from Bethel to communities along the ice road in all but the most extreme weather—instead of being flown in on light aircraft when that method was not made impossible by the fickle weather of the Lower Kuskokwim. This resulted in a significant cost savings for freight between Bethel and the villages.

The ice road also enables other critical services such as mail delivery, access by the State troopers, and medical services. In addition, village residents can access the hospital and other government services in Bethel even when air taxis are grounded. The Alaska Department of Transportation and Public Facilities acknowledged the public transportation benefit of ice roads in 2020 by contributing both State and Federal funding toward the construction,

Representatives from FHWA, villages served by the Kuskokwim Ice Road, the Bureau of Indian Affairs, and the University of Alaska Fairbanks met in Bethel, AK, for a peer exchange in March 2020.

Source: FHWA.

maintenance, and operation of the Kuskokwim Ice Road.

At the peer exchange, as representatives from several of the communities affected by the ice road told their stories, it became clear that the ice road meant more than the lower cost of freight. Community members commented that the ice road is a source of pride for the communities along the route, creating a bond that few other projects could ever produce.

The ice road also freed communities from the unpredictable weather that makes air traffic unreliable. Ice roads offer not only the prospect of dependable freight movement, but also an alternative to air medivac for the sick or injured when the weather does not allow flights. Other community members discussed the ability to visit friends and relatives and attend regional events, such as watching their children play basketball in the next village.

In short, the ice road means freedom to safely travel along the river in winter as well as in summer, when the river enables travel by boat or barge and all-terrain vehicles provide overland travel on trails that are impassable in winter.

Addressing Challenges in Ice Road Design

The FHWA Office of Tribal Transportation understands the importance of ice roads to communities along Alaskan rivers. While the work of people like Mark Leary and his crew is impressive, the lack of standards poses a potential public safety concern. Standards include the determination of ice thickness required to carry the expected traffic and the selection of routes, maintenance standards, speed limits, and traffic control devices.

To address this gap, the Office of Tribal Transportation has published information on how to establish and maintain ice roads in the *Tribal Transportation Program Delivery Guide*, available at *https://highways.dot.gov/federal-lands/programs-tribal/guide/tribal-transportation-program-delivery-guide*. In addition, the FHWA Office of Federal Lands Highway is funding research to establish these standards, and has selected the University of Alaska to lead the effort.

The variability in the ice and river characteristics throughout the winter months creates one of the most challenging environments in which to design, construct, and maintain a transportation corridor. The safety of an ice road requires an understanding of the properties of ice, which vary with how it was formed, its temperature, and the rate at which it is loaded (vehicle speed). How to design, construct, and maintain ice roads can vary from a highly mathematical approach based on ice mechanics and structural analysis of plates to a fully

Taking a core sample of ice, like this one from the Tanana Ice Bridge, provides information about the quality and type of ice in addition to measuring the thickness.

© 2020 Svetlana Stuefer, University of Alaska Fairbanks.

The thickness of the ice can be measured using an auger, as shown here, but this method enables monitoring only at individual locations.

© 2021 Nathan Belz, University of Alaska Fairbanks.

empirical approach based on the experience of those involved. In practice, the process blends these two approaches because of the variability of ice type and thickness along the routes and because of the changing characteristics of the rivers.

As part of the research effort, the team conducted a literature review of existing guidelines such as those developed in Canada for Alberta, the Northwest Territories, and Nunavut. The literature shows that the most common design for ice roads derives from mathematical equations tempered with empirical coefficients based on acceptable risk levels. The use of a risk management framework provides a means of balancing user needs and requirements with the resources available to the ice road operators. The final design depends on the type of ice, ice thickness, anticipated ice temperatures, vehicle weights, and traffic speeds. Ice road operators can manage all of these factors except the type of ice and its temperature.

Ice thickness must be continuously monitored during road construction and throughout the winter. One of the most common methods of monitoring the ice thickness is simply to drill a small hole in the ice using small hand or powered augers. A thickness gauge with a hook attached to the bottom is then fed through the ice and pulled up against the bottom of the ice. While this method is accurate, it only allows for the measurement of ice at discrete points.

Ground-penetrating radar (GPR), commonly used to obtained continuous ice thickness, proves to be a helpful tool but has limitations. While GPR can identify individual layers, it cannot distinguish one type of ice from another. Nor is it useful when water flows over the surface of the ice or between ice layers. Consequently, GPR is best used in conjunction with conventional ice assessments and thickness measurements.

Generally, the thickness of the ice as the river or lake freezes and human experience dictates the routing of ice roads. Alaska's rivers are geologically young. As a result, their channels change frequently, which alters the optimal routing each year. Further, the routing may vary through the winter if the thickness of the ice falls below minimal thickness because of water conditions, or if cracking occurs as the result of loading.

Cracking from vehicle loading constitutes a major safety hazard to travelers because of the danger of falling through the ice. While ice thickness, vehicle weight, and vehicle speed help manage this risk, cracking can and does occur. In these cases, agencies can apply remediation and repair techniques such as surface flooding to increase the thickness of the ice and in effect glue the cracks together. If cracking is severe enough, the location of the ice road may change.

Ground-penetrating radar (GPR) can quickly map ice depth, but does not distinguish one type of ice from another and cannot work if water flows over the ice or between the layers.
Source: FHWA.

Unmanned aerial vehicles (UAVs)—or drones—fitted with the appropriate sensors can scout appropriate routes and detect thin ice and cracks in the ice without putting workers in harm's way. The use of UAVs for this purpose is fairly new. As part of the research project, the University of Alaska Fairbanks will investigate which sensors may be required and which aircraft are appropriate for the task. UAV data will likely be used in concert with GPR and ice thickness measurements to assess the health of the ice sheet.

Signage for Ice Road Safety

Keeping the public safe on the ice continues to be the greatest challenge of creating and maintaining ice roads. Ice conditions, speed limits, weight restrictions, and delineation all require constant communication with the public. Signage offers a critical tool in that communication. Signs at entry points can show the level of risk and remind travelers to check public information sources and any other necessary warnings. While there are a few existing destination signs and warning signs in use, these signs do not meet current signage standards. Improved signs meeting the requirements in the *Manual on Uniform Traffic Control Devices*, including the sign size, color, and placement, are expected to be installed during the winter of 2022.

Founding these devices on the ice presents unique challenges. While signposts

Temporary signs, like this one, warn drivers about hazards on the ice roads.
© Mark Leary, Native Village of Napaimute.

Warning signs remind travelers that road conditions may change. The arrow marked KLG indicates the direction of Kalskag, AK.
© Mark Leary, Native Village of Napaimute.

can be embedded in the ice, they must be removed before spring thaw. The timing is critical because the signs need to remain in place as long as safely possible. If the operators wait too long, the signs cannot be safely removed and will be lost. While general guidance can be given, the timing will vary each year based on conditions and must rely on the judgment of the operator.

Signage for speed limits is critical. Speed limits on ice roads not only ensure that the vehicle can traverse the route, but also serve to protect travelers and the road itself. Following maximum speed postings guarantees that the ice does not break because of the wave that is generated in the water ahead of the loading. If the speed is too great, the wave becomes large enough to generate tension in the surface of the ice, which results in radial cracking. Radial cracking provides the last warning before the vehicle falls through the ice.

Public Information

Hazardous conditions, like open holes and thin ice, can develop throughout the winter. Travelers on the ice roads need to be aware of these conditions. Local crews or operators will commonly mark hazardous areas using willows around the perimeter of the hazard. In some cases, these willows are wrapped with reflective tape to improve visibility during the long hours of winter darkness. Social media is also used to spread the word about incidents and hazards. However, no formal system currently exists for distributing public information about ice road conditions.

FHWA's Tribal Transportation Program Safety Fund awarded a grant to the Native Village of Napaimute to develop a public information app or website. In partnership with other entities involved in the management of the ice roads, the village hopes to deploy a pilot of the system by the end of 2021.

The Future of Ice Roads

Construction and operation of ice roads present numerous challenges. After listening to the users of the Kuskokwim River Ice Road, it is clear that the value of ice roads to village residents far exceeds the costs associated with the road. While some costs, such as freight expenses can be quantified, the benefits of watching a child play basketball or visiting friends and family in adjacent villages cannot be calculated.

The cost of conventional roads makes their construction in the region unlikely. Consequently, river, trail, and air travel offer the only viable options.

The FHWA Office of Tribal Transportation and the University of Alaska's Arctic Infrastructure Development Center recognize the need for uniform practices related to the design, construction, and operation of ice roads. The manual being developed under FHWA funding will help ensure the safety of those who are increasingly dependent on ice roads.

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For more information, see *https://cset.uaf.edu* or contact Adam Larsen at 306-619-2601 or *adam.larsen@dot.gov* or Billy Connor at 907-474-5550 or *bgconnor@alaska.edu*.

BOLSTERING THE SAFETY OF AMERICA'S BRIDGES FOR HALF A CENTURY

FHWA's national bridge inspection program marks 50 years of improving safety.

by **JOEY HARTMANN**

It is in the vital interest of the United States to have a strong national bridge inspection program and maintain an inventory of the Nation's bridges. Regular and thorough bridge inspections are necessary to maintain safe operations and prevent structural and functional failures. In addition, data on the condition and performance of bridges are necessary for bridge owners to make informed investment decisions as part of an asset management program.

Safety—including bridge safety—is the Federal Highway Administration's top priority. The agency's longstanding and successful national bridge inspection program has been at the core of highway bridge safety, and 2021 commemorates its 50th anniversary. The program requires regular bridge inspections and data collection by trained professionals.

FHWA adopted the National Bridge Inspection Standards (NBIS) regulations in 1971, prompted by the U.S. Congress enacting the Federal-Aid Highway Act of 1968. The NBIS were the direct result of the Silver Bridge collapse in Point Pleasant, WV, on December 15, 1967. The tragic event brought nationwide attention to the issue of bridge safety and led to a systematic effort to ensure bridge safety at the national level—and the birth of FHWA's Federal program. It was an event of historical significance and one

The Federal Highway Administration adopted the National Bridge Inspection Standards (NBIS) in 1971. Bridges, like this one on Foothills Parkway in Tennessee, are inspected following the program's standards.

Source: FHWA.

that many would agree was a wake-up call that propelled the Nation into a new era of bridge safety.

By 1971, when the NBIS were established, the new standards required that bridges, and their various component parts—ranging from pilings to deck slab—be inspected at least once every 2 years, with special emphasis on identifying and assessing fractures, corrosion, and fatigue. In addition, FHWA was ultimately charged with using the data from bridge inspections nationwide to create the National Bridge Inventory (NBI) and to standardize bridge inspector qualifications.

"The Silver Bridge tragedy and the resulting legislation drastically changed the way we approached bridge safety and made sure that the hundreds of millions of Americans who have driven over a bridge any time in the last 50 years were safer in doing so," says Thomas D. Everett, FHWA's Executive Director.

In addition, the tragedy raised many questions about the state of bridges nationally. For starters—How many bridges were there in the United States? How were they designed, what were they made of, and how old were they? How much traffic did they carry? There were no answers to basic questions like these, because there was not yet a nationwide collection of bridge information. The establishment of the NBIS aimed to answer these questions.

A half century later, FHWA's bridge inspection standards continue to ensure that only bridges safe for travel are open to traffic.

A Robust Program

FHWA provides oversight of State bridge inspection programs. While States, local agencies, Federal agencies such as the National Park Service, and Tribal governments own most highway bridges, FHWA maintains the NBIS—the Federal bridge inspection regulations that States, Federal agencies, and Tribal governments are required to follow. The NBIS apply to all highway bridges on all public roads. FHWA assesses compliance with the regulations through a detailed annual review process.

Working with FHWA division offices, State transportation departments, and Federal agencies, hundreds of qualified inspectors from the NBIS program evaluate the condition and safety of the Nation's highway bridges every day. These bridges are inspected on a routine basis, typically every 24 months, and the results are reported to FHWA. If inspectors deem a bridge unsafe, immediate action is taken, which may include closure, prompt repair, or load posting (weight limit) that does not allow heavy vehicles to use the bridge.

FHWA continues to maintain the comprehensive NBI, a compilation of bridge data that States and Federal agencies provide to FHWA on an annual basis.

Timeline of Bridge Program Evolution

Over the last decade, FHWA has implemented new measures to boost its oversight role and to target the inspection of areas critical to bridge safety. For example:

- In 2011, FHWA instituted a risk-based, data-driven approach to more clearly and easily identify bridge inspection issues in each State. FHWA replaced written general assessments of State bridge inspection programs with measurements of 23 key metrics to more easily identify potential safety issues. The newer process provides for more bridge inspection consistency and simplifies efforts to identify challenges State by State.
- In 2015, FHWA began collecting new data for bridges on the National Highway System to more closely monitor bridge conditions nationwide. Previously, bridge inspectors assigned one summary rating for the condition of a bridge's major components to reflect both the severity of a problem and whether it was widespread or confined to a small area. The new format calls for each square foot of the bridge deck to be assigned a rating, and its other elements—such as the joint seals—receive separate ratings. Dividing bridge components into smaller, more manageable elements helps engineers more easily assess the extent of bridge deterioration, which leads to more informed decisions about preservation, repair, and replacement.
- FHWA is in the process of updating the NBIS. A Notice of Proposed Rulemaking was published on November 12, 2019, and the comment period was open until March 13, 2020. FHWA has been reviewing the comments received and is preparing a Final Rule.

An inspection of the John Coffee Memorial Bridge, part of the Natchez Trace Parkway over the Tennessee River.

Source: FHWA.

It contains more than 100 data items for each of the Nation's approximately 618,000 highway bridges, representing a database of more than 60 million pieces of information.

"FHWA's NBI has gotten more robust over the years. Just looking at the data amassed in the 21st century, the number of highway bridges has grown from 587,735 in 2000 to 618,456 today," says Hari Kalla, the Associate Administrator for the FHWA Office of Infrastructure. "Bridge owners continue to build new bridges and replace or rehabilitate others that have deteriorated. Today, the average age of the 618,000 highway bridges in the NBI is 45 years old. The oldest bridge in the NBI is in Pennsylvania and was built in 1697. In fact, there are more than 1,700 bridges built before 1900 that are still being used today."

The program has been successful in identifying bridge deficiencies, while Federal and other funding programs have supported efforts to address these deficiencies. As owners have repaired bridges, the percentage of bridges in poor condition has dropped from 11.9 percent in 2000 to 7.3 percent in 2020. Bridge conditions have steadily improved over the years due to the commitment to bridge safety by FHWA and State departments of transportation.

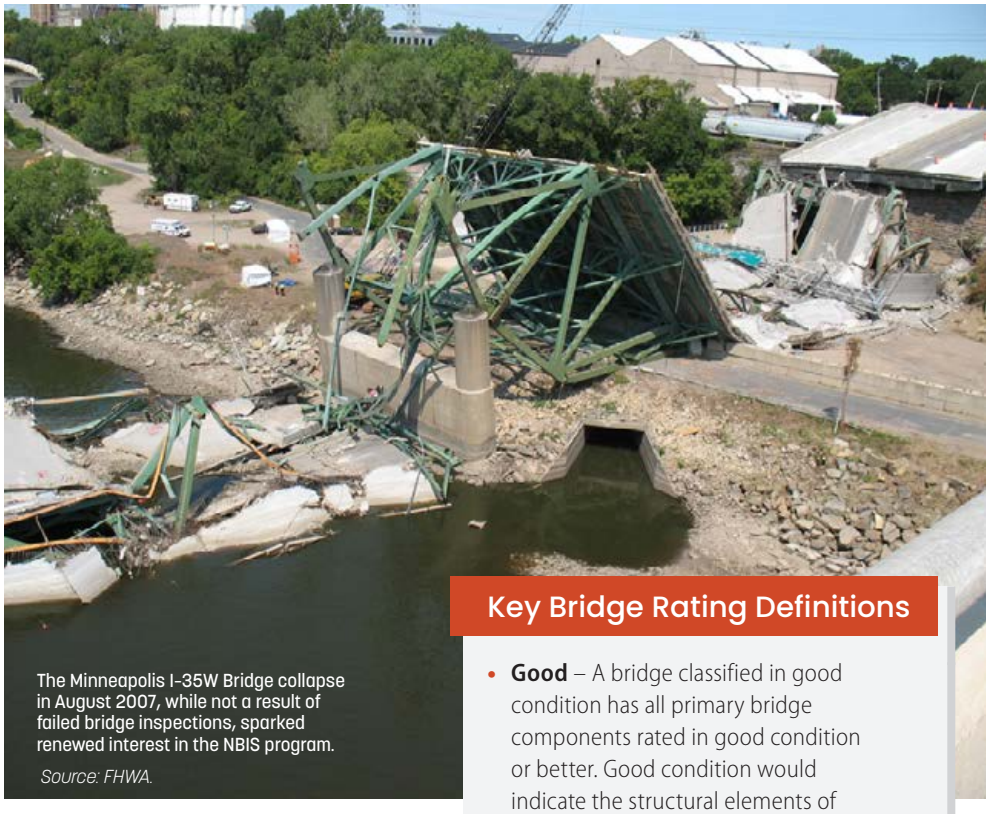
While State departments of transportation are on the front lines conducting the inspections, FHWA provides the standards and oversees State programs to ensure safety and track bridge conditions nationwide. FHWA has worked constantly over the years to improve the national program and ensure that bridge inspections continue to be robust.

The agency is continually committed to finding new and better ways of making sure bridges are safe.

Flexible Response to Bridge Safety Challenges

Since FHWA established NBIS regulations in 1971, the agency has worked to evolve, improve, and refine the program on an ongoing basis. Some improvements have included requiring more rigorous inspections for certain steel bridges with less redundancy, requiring underwater inspections for bridges over water, and taking appropriate and timely followup actions when inspections identify critical safety issues. FHWA has also updated training requirements for bridge inspectors.

Another bridge tragedy occurred on August 1, 2007, when the Minneapolis I–35W Bridge collapsed during evening rush hour. Although the collapse was not a result of a failed inspection, it brought renewed interest in the bridge inspection program.



The Minneapolis I-35W Bridge collapse in August 2007, while not a result of failed bridge inspections, sparked renewed interest in the NBIS program.

Source: FHWA.

In response, FHWA moved from a qualitative process to a risk-based, data-driven process in 2011 to assess compliance with the NBIS. FHWA now requires annual assessments using a grid of 23 specific inspection program areas to determine how well State transportation departments and Federal agencies are meeting the regulations. In addition, FHWA dedicated more staff to support bridge inspection efforts. The aim was to improve consistency in bridge inspections and simplify efforts to identify challenges State by State. FHWA also expanded the amount of data collected on bridges to more closely monitor bridge conditions nationwide.

Tradition Alongside Technology

FHWA continues to explore new ways of keeping bridges safe, including using unmanned aerial vehicles, also known as drones, and various other cutting-edge tools to support or assist bridge inspections. Applying science and technology to such matters helps inspect bridges more quickly, and more thoroughly, than ever before. On any given day, hundreds of bridges are being inspected across the country and evaluated by qualified inspectors.

Key Bridge Rating Definitions

- **Good** – A bridge classified in good condition has all primary bridge components rated in good condition or better. Good condition would indicate the structural elements of the bridge have no deterioration or some minor deterioration. A bridge in good condition may need preservation or cyclic maintenance activities.
- **Fair** – A bridge classified in fair condition has one or more primary bridge components rated in satisfactory or fair condition, and none of these components rated worse than fair condition. Fair condition would indicate that some structural elements of the bridge have minor deterioration that could include section loss, cracking, spalling, scour, or other defects of similar significance. Typical needs of a bridge in fair condition would include preservation, cyclic maintenance activities, or condition-based maintenance activities.
- **Poor** – A bridge classified in poor condition has one or more primary bridge components rated in poor or worse condition. Poor condition would indicate that some structural elements of the bridge have advanced deterioration. Typical needs of a bridge in poor condition would include condition-based maintenance activities, rehabilitation, or replacement. A bridge in poor condition may require more frequent inspections, closer monitoring, or weight restrictions to ensure it remains safe for public travel. Unsafe bridges are closed.

Inspectors perform ultrasonic testing, a nondestructive evaluation technique, on two bridges.

Source: FHWA.

Bridge Inspection Technologies

- Acoustic emissions testing
- Acoustic wave sonic/ultrasonic testing
- Dye penetrant testing
- Magnetic particle testing
- Magnetic flux leakage testing
- Eddy current testing
- Ground-penetrating radar
- Stress wave/pulse velocity testing
- Impact echo testing
- Infrared thermography
- Magnetic field disturbance testing
- Radiographic and other nuclear methods
- Vibration testing

Despite certain advances in technology, however, physical and visual inspection methods continue to be valuable in the inspection world. These remain the primary tools in the toolbox that bridge inspectors use in assessing the condition of a bridge. Other technology-based tools used by bridge inspectors are sometimes referred to as advanced inspection methods, or nondestructive evaluation (NDE) techniques. These include methods such as ultrasonic testing, which uses sound much like a sonogram to detect subsurface characteristics, and infrared thermography, which uses the heat radiating from bridge components as an indicator of their condition.

"In addition to traditional, manual methods, the bridge inspection industry has embraced technological advances when they can add value to the inspection results," says Cheryl Richter, Director of the FHWA Office of Infrastructure Research and Development.

FHWA supports the use of advanced technology, including the use of drones, to supplement bridge inspections. Technologies may not replace the human inspector at this time, but they can accelerate inspections and improve inspector safety. NDE technologies can be used to improve the accuracy of some inspections and the proper identification of certain issues. Bridge inspectors are trained to identify when those technologies are needed.

Looking Toward the Future

FHWA is in the process of updating the NBIS to address statutory requirements, provide flexibility, and address ambiguities identified since the last update to the regulation in 2009. The improvements will include expanding the requirements to Tribally owned highway bridges, updating the training and qualifications for bridge inspectors, and establishing a national certification for inspectors. In addition, requirements for the intervals between inspections will be updated using a risk-based approach, and procedures for the reporting and monitoring of critical findings will be established. The changes are primarily aimed at ensuring the uniformity of inspections and evaluations and clarifying responsibilities.

JOSEPH (JOEY) HARTMANN, Ph.D., P.E., is the director of FHWA's Office of Bridges and Structures.

For more information, contact Joey Hartmann at *joey.hartmann@dot.gov* or visit *www.fhwa.dot.gov/bridge*.

Inspectors use a bucket truck on the Snake River Bridge in Grand Teton National Park.

Source: FHWA.

Source: FHWA.

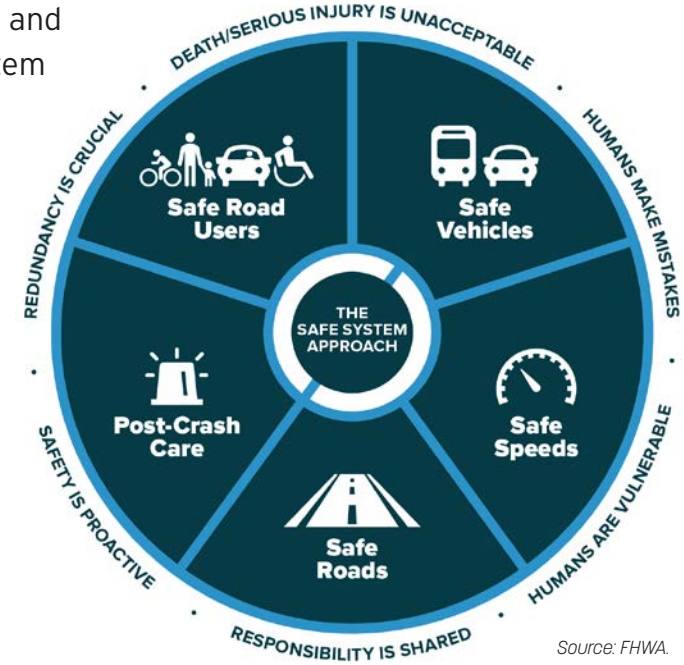
ZERO IS OUR GOAL

A SAFE SYSTEM IS HOW WE GET THERE

Source: FHWA.

Zero traffic deaths or serious injuries is our goal, and the Winter 2022 issue of *Public Roads* will highlight the revolutionary Safe System Approach that transportation leaders are advancing to help us get there.

- Discover how a growing number of cities, States, and countries are successfully applying the Safe System Approach to reach zero traffic deaths and serious injuries
- Learn about how FHWA is making strides to advance the Safe System Approach in safety funding, planning, and programs, including strategic highway safety plans, intersections, and speed management
- Learn about how NHTSA is integrating the Safe System Approach to protect all road users, support safe vehicle technology, and emphasize post-crash care
- Be inspired to advance the Safe System Approach in your community to reach zero deaths and serious injuries

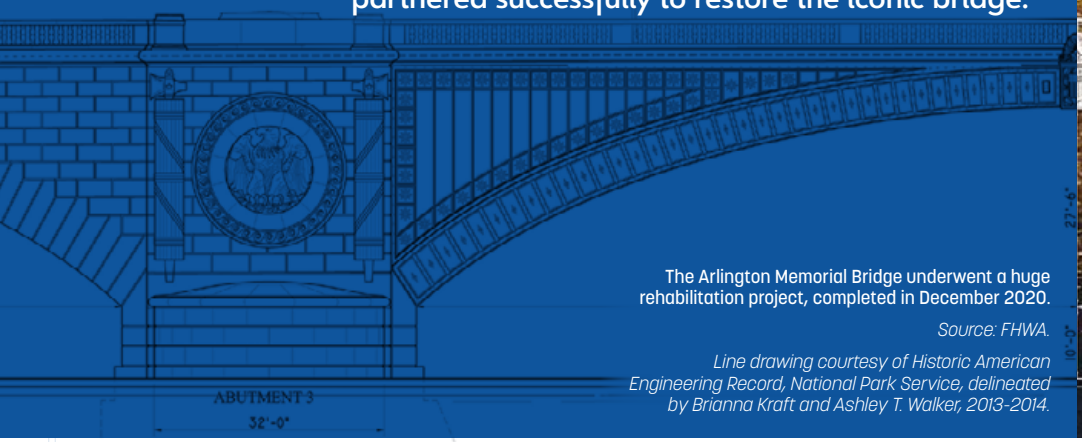


Source: FHWA.

Be sure to check out the next issue of *Public Roads*!

REHABILITATING the Historic ARLINGTON MEMORIAL BRIDGE

The National Park Service and the Federal Highway Administration partnered successfully to restore the iconic bridge.



The Arlington Memorial Bridge underwent a huge rehabilitation project, completed in December 2020.

Source: FHWA.

Line drawing courtesy of Historic American Engineering Record, National Park Service, delineated by Brianna Kraft and Ashley T. Walker, 2013-2014.

by **SANDY SINCLAIR**

Since 1932, the Arlington Memorial Bridge has been a lasting symbol of national unity after the Civil War. Spanning the Potomac River, the neoclassical bridge links the Lincoln Memorial in Washington, DC; Arlington House (also known as the Robert E. Lee Memorial) in Arlington, VA; and Arlington National Cemetery—the final resting place for more than 400,000 service members who died on active duty, veterans, and their family members.

"Arches of Ever-Enduring Granite"

The Arlington Memorial Bridge is the realization of nearly a century of imagination, speculation, and planning. President Andrew Jackson envisioned a bridge over the Potomac River during his term in office from 1829 to 1837, and in 1851, Secretary of State Daniel Webster credited the former president for championing a bridge "with arches of ever-enduring granite, symbolical of the firmly established union of the North and South."

Decades of periodic studies into the feasibility of a bridge, and even a design competition in 1899, generated little more than paperwork. On his final day in office in 1913, President William Howard Taft authorized $25,000 for a commission to investigate how to link Arlington National Cemetery to the District of Columbia across the Potomac River. Funding shortfalls and other delays prevented the bridge from becoming a reality until President Calvin Coolidge approved construction. The bridge cost about $7 million and was dedicated on January 16, 1932.

Today, Arlington Memorial Bridge is one of the five vehicular bridges connecting the District of Columbia and Virginia and serves as an iconic element of the entrance to the Nation's Capital. Decades of gradually increasing vehicle traffic, vehicle tonnage, weather, and the natural freeze-thaw cycle aged the bridge severely. By the early 21st century, it was in serious need of repair.

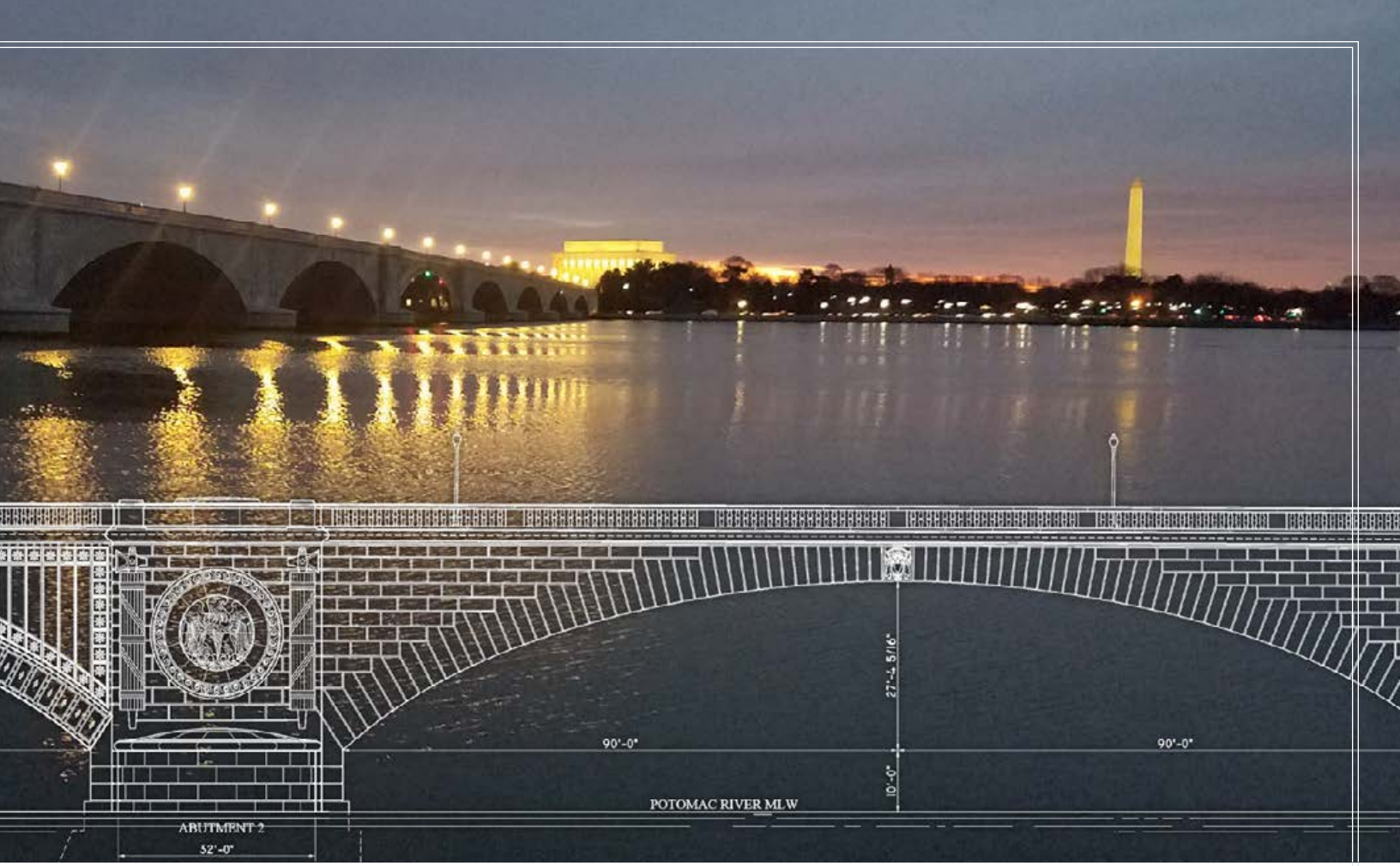
The bridge is a key component of the greater Washington, DC, area transportation network, with an estimated 68,000 vehicles crossing the bridge daily. The bridge is also designated as an emergency evacuation route for the Nation's Capital.

Since it first opened to traffic, the bridge structure had never been rehabilitated at this magnitude. Following guidelines from the Federal Highway Administration's National Bridge Inspection program, bridge inspectors noted that components of the bridge had deteriorated to a critical level. The National Park Service (NPS), which has jurisdiction over the bridge because of its status as a national monument, conducted a series of temporary emergency repair projects on the bridge between 2010 and 2017. Despite these efforts, Federal officials determined that—without substantial renovation—the bridge would be forced to close by 2021.

NPS and FHWA Partnership

With the Arlington Memorial Bridge serving as both a monument and a connector, NPS and FHWA shared a mutual interest in preserving the bridge and keeping the public safe. The two agencies worked together to restore the historic bridge to its original grandeur and in 2018 began a 3-year, $227 million program to make the most comprehensive set of repairs to the bridge since its original construction.

The design-build project repaired or replaced the bridge deck, sidewalk, and bascule (drawbridge) span, and restored the remainder of the structure. The work extended the bridge's useful life for 75 years. In December 2020, NPS completely reopened the rehabilitated bridge.



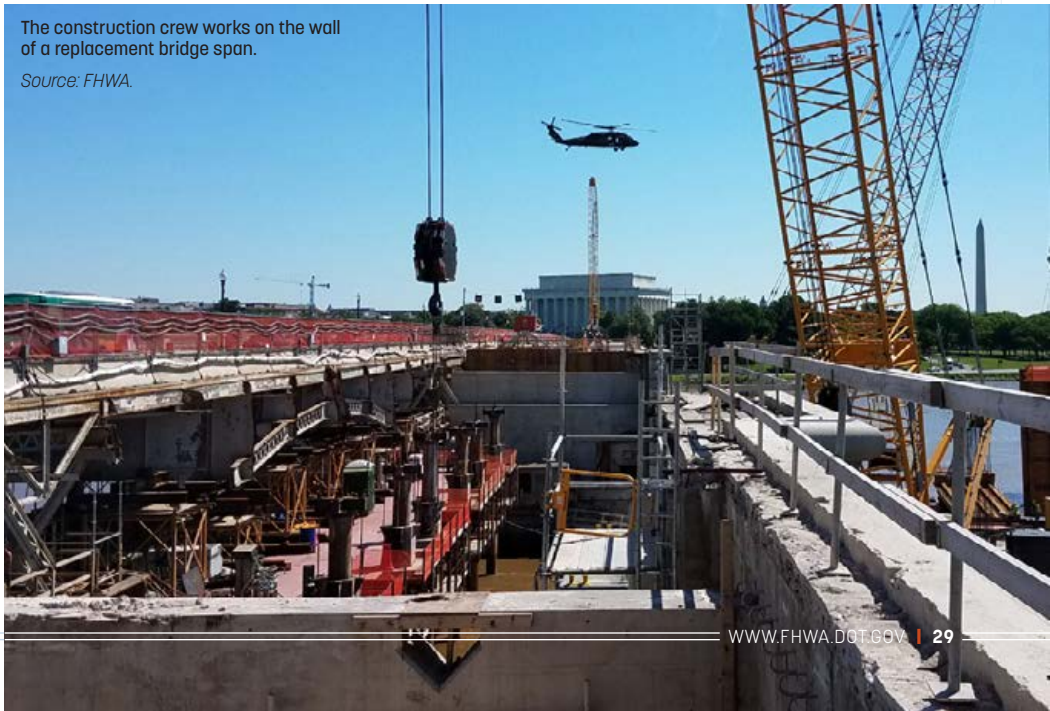
"I am very honored to have been part of this large historic rehabilitation project," says FHWA construction engineer Joe Fabis. "The coordination with Federal agencies, local agencies, contractors, subcontractors, and suppliers that led this project to be completed on time kept this bridge in service for the local community and for visitors from all over the world."

Replacing the Historic Bascule Span

By many accounts, at 94 feet (29 meters) wide and 2,162 feet (659 meters) long, the Arlington Memorial Bridge is a structural masterpiece. The bridge consists of 10 reinforced concrete arch approach spans and features a 216-foot (66-meter) double-leaf bascule span at its center. The bascule span was the longest, heaviest, and fastest opening in the world when it was built, but it has not functioned since 1961 because the closed position provided sufficient clearance for the navigational traffic below after that time. The steel experienced significant rust and section loss during this time of disuse.

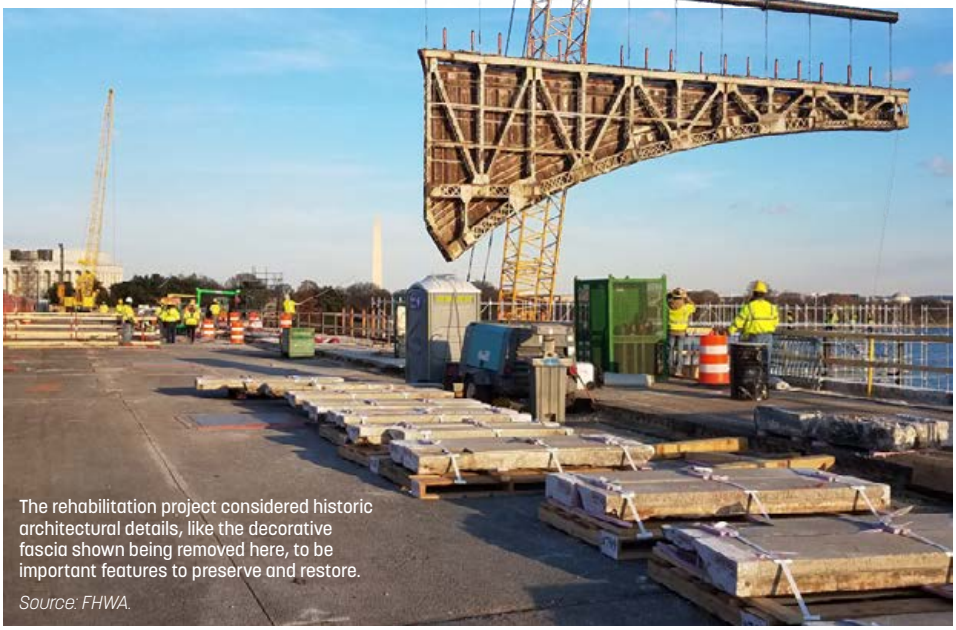
Between the bridge's completed construction in 1932 and the drawbridge closure in 1961, the bascule span would periodically open and close to provide access for large ships to the Georgetown waterfront. Over time, as shipping traffic on the Potomac River decreased and the construction of a fixed, low-clearance bridge nearby ended access for large ships, the bascule span was permanently closed in 1965. With no ship traffic, there was no expectation it would ever need to open again.

The rehabilitation of the Arlington Memorial Bridge was one of the largest and most important infrastructure projects in NPS history. In 2016, the project team completed the required environmental assessment under the National Environmental Policy Act (NEPA). The assessment's preferred alternative for the project prioritized historic preservation by combining a mixture of replacement and rehabilitation practices to preserve the structure's original character. During the NEPA review process, the project team considered multiple proposals for the bascule span replacement in coordination with the historic preservation offices of Virginia and the District of



The construction crew works on the wall of a replacement bridge span.

Source: FHWA.



The rehabilitation project considered historic architectural details, like the decorative fascia shown being removed here, to be important features to preserve and restore.

Source: FHWA.

Columbia, the U.S. Commission of Fine Arts, and the National Capital Planning Commission. The final plan called for the bridge's bascule span to be replaced with a new fixed span comprised of variable-depth steel girders.

Designing to Reduce Future Maintenance

The deterioration of the bridge prior to construction occurred in part because of the intrusion of water and winter salting for snow. The design of the new structure prevents water and chlorides from entering the bridge. The new center span design also supports the roadway above using multiple simple plate girders, adding redundancy compared to the original complex two truss-floor beam system with lattice steel members. The new design reduces the amount of future maintenance needed compared to the original. The renovation integrated several FHWA initiatives to preserve the bridge and minimize construction time, including accelerated bridge construction techniques, prefabricated bridge element systems, and the use of ultra-high performance concrete, which will also help future maintenance. In addition, passive corrosion anodes help reduce chloride corrosion. These initiatives, along with a concrete overlay, delivered a final watertight bridge and reduced construction duration and long-term maintenance.

"The FHWA initiatives we used promoted durability and minimized impact to the public," says FHWA structural engineer Hratch (Rich) Pakhchanian, who helped lead the restoration project. "These methods, with cutting-edge construction and materials technology, accelerated our construction schedule."

The design team also faced challenges related to the bridge's sidewalks, which enabled water to enter the bridge at the interface between the deck and the sidewalk. Though mainly at the center span, water and road salts could reach the steel members and turned out to be one of the primary contributing factors to the steel's corrosion issues. The new deck extends below the sidewalk to prevent water from entering the bridge.

The existing bascule span had exterior fascia girders with floor beams holding up the structure. To replace it while minimizing impacts to bridge traffic, the project team created a working platform atop the water using a specially designed "jack-up barge" of 22 "flexi-floats" with shoring towers supported by pipe pile. The barge and shoring towers supported the floor beams on the bascule span, enabling workers to cut the bascule span in half while live traffic drove overhead.

The construction replaced the existing concrete deck using accelerated bridge construction techniques with more than 450 full-depth precast concrete deck panels. The use of precast concrete enabled the deck to be assembled in a controlled environment, rather than cast in place at the project site, where additional variables—from air temperature, humidity, precipitation, and evaporation to materials delayed by periodic traffic congestion—could have resulted in considerable delays and increased costs. The offsite production meant that the precast deck panels could be constructed and stored until needed onsite. This led to more control of the schedule, reducing weather and supplier impacts and unanticipated cold joints. The project used stainless steel reinforcing in the precast deck panels to further improve quality, which significantly reduced concerns of possible corrosion in steel reinforcements.

The project team used floating barges to help with the rehabilitation. Here, the underside of the replaced bascule span is visible.

Source: FHWA.

The project used precast concrete bridge deck panels to shorten construction time and minimize future maintenance needs.

Source: FHWA.

Preserving Historic Elements

NPS and FHWA committed to preserving as much of the structure's unique design elements as possible while incorporating engineering and construction materials and methods that would extend the life of the bridge. To maintain the original look of the bascule span/drawbridge, the project used a fixed span bridge with 216-foot-long (65.8-meter-long), 170,000-pound (77,000-kilogram) high-performance steel plate girders, along with 70 kilopound per square inch (ksi) (480 megapascal) bottom flanges and 50 ksi (340 megapascal) top flanges.

"The Arlington Memorial Bridge project highlights the exceptional work National Park Service and Federal Highway Administration staff accomplished together," says Charles Cuvelier, superintendent of the George Washington Memorial Parkway, which connects to the bridge. "Our collaboration helped protect this iconic memorial and ensure it will continue to serve as a reminder of the sacrifices of our Nation's veterans and as a symbolic link between the north and the south for decades to come."

Once installed, the fitted trusses underneath the girders recreated the original shape of the historic bascule span/drawbridge. Additionally, NPS considered the original pop-up protective bollards on the bascule span/drawbridge to be a historic element of the bridge and developed a design to preserve the posts in place.

Throughout construction, NPS and FHWA took special care to protect the bridge's historic architecture and enhance its iconic appearance. Since work began in 2018, workers methodically removed, cleaned, repaired, and reinstalled more than 4,500 pieces of granite and rehabilitated the bridge's historic structure.

"The partnership between FHWA and NPS was key to the success of this project," says FHWA's lead structural engineer George Choubah. "Everyone on the team worked very hard to make sure that the fast-paced design and construction schedules were met without jeopardizing the quality of the final product."

In addition to upgrading this historic bridge to contemporary standards, and restoring its role as an integral part of the efficient flow of traffic in the Nation's Capital for decades to come, the rehabilitation of the Arlington Memorial Bridge has given new life to the most prominent of entrances to the District of Columbia.

Working with NPS, FHWA tackled an urgent and complicated infrastructure challenge head-on. The project succeeded in rehabilitating the national Capital's ceremonial entrance and preserving its historic character for future generations.

ALEXANDER (SANDY) SINCLAIR is a public affairs specialist in FHWA's Office of Public Affairs, where he helps promote the agency's multifaceted agenda to the media, stakeholders, and FHWA employees. With the Department since 1999, Sinclair graduated from the University of California-Los Angeles with a bachelor's degree in political science.

For more information, see *www.nps.gov/gwmp/learn/management/amb-rehabilitation.htm*.

The rehabilitation project replaced the bascule span, which had not been used since 1961, while maintaining the bridge's historic look.

Source: FHWA.

Along the Road is the place to look for information about current and upcoming activities, developments, trends, and items of general interest to the highway community. This information comes from U.S. Department of Transportation sources unless otherwise indicated. Your suggestions and input are welcome. Let's meet along the road.

Public Information and Information Exchange

FHWA's MATCH program offers mentoring to local and Tribal agencies to improve roadway safety.

Source: FHWA.

FHWA Launches MATCH for Local and Tribal Agencies

The Federal Highway Administration recently launched the Mentoring, Assistance, Training, and Communication Help (MATCH) program to provide broad-based technical assistance to local and Tribal agencies facing roadway safety challenges. The program connects agencies requesting assistance (mentees) with peer mentors who have specific expertise to help successfully address the identified challenges. The technical assistance is free for mentees, and mentors volunteer their time to help peers.

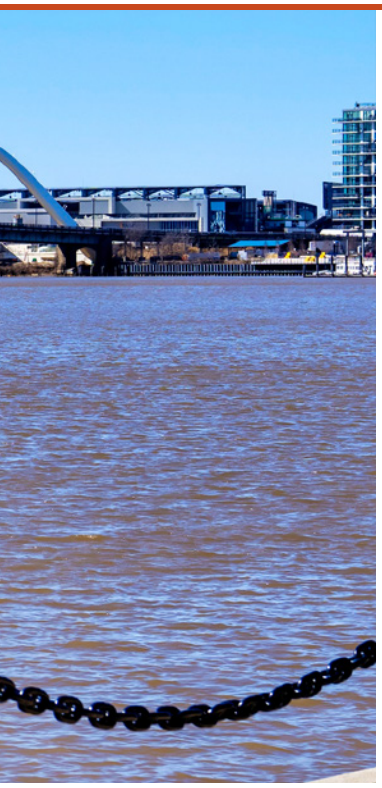
Local and Tribal agencies own and operate approximately 75 percent of the Nation's roadway network, much of which is in rural areas. These agencies often face unique safety challenges on their roads involving roadway departures, intersection safety, speed management, and pedestrian and bicyclist safety. The MATCH program will augment FHWA efforts and support local and Tribal road practitioners with integrating safety into their roadway programs. The program leverages the mentor's knowledge and experience to provide short-term technical assistance to local and Tribal agencies wanting to resolve safety or safety-related concerns or issues. Mentors will assist in identifying the problem and recommend appropriate implementation strategies when paired with mentees. This enables mentee agencies to benefit from this knowledge to potentially save lives and reduce serious injuries on roadways.

All local and Tribal agencies are eligible to apply for technical assistance from a mentor through the MATCH program. Public agency transportation safety professionals and those from centers of learning who have specific expertise related to local or Tribal road safety can serve as mentors. Mentors must be actively employed by or retired from a public transportation agency and have a minimum of 5 years of continuous transportation safety experience. Both mentors and mentees will be required to produce a short report once the activity is completed to document and share noteworthy practices.

For more information, visit *https://safety.fhwa.dot.gov/local_rural/MATCH* or contact Rosemarie Anderson at *rosemarie.anderson@dot.gov*.

USDOT Announces Expanded Workforce Pilot Programs

In May, U.S. Transportation Secretary Pete Buttigieg announced expanded construction hiring and workforce development pilot programs to be managed by FHWA and the Federal Transit Administration. Buttigieg made the announcement at an event at the construction site of the new Frederick Douglass Memorial



The new Frederick Douglass Memorial Bridge in Washington, DC, is the city's largest ever public works project.

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Bridge, where he joined Washington, DC, Mayor Muriel Bowser; the director of the District Department of Transportation; and other Federal and local leaders. The bridge replacement project is the largest public works project in DC history and is tentatively scheduled to open in fall 2021.

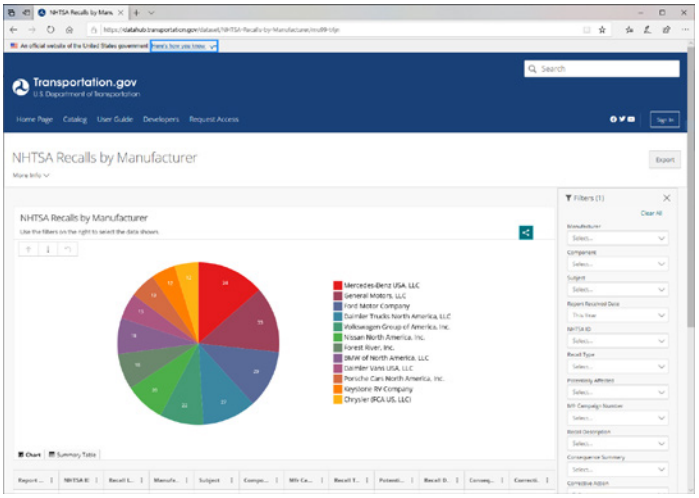
Both FHWA's and FTA's programs will give contracting agencies expanded flexibility to use hiring preferences to enhance workforce development opportunities for those in economically or socially disadvantaged communities. A similar USDOT pilot program was in effect from 2015 to 2017. The local hire initiatives will improve participation in existing training and apprenticeship programs, such as FHWA's on-the-job training programs.

FHWA's Enhancing Workforce Development Opportunities Contracting Initiative will help to rebuild the skilled workforce needed to improve the Nation's transportation infrastructure. The 4-year pilot program will enable State transportation agencies and contractors to better recruit qualified construction workers, which can be challenging in many parts of the country.

For more information on FHWA's pilot program, visit *www.fhwa.dot.gov/construction/workforcedevelopment*. For more information on the bridge project, visit *www.newfrederickdouglassbridge.com*.

NHTSA Launches Recall Dashboard

In July, the National Highway Traffic Safety Administration unveiled a new cloud-based recall dashboard to make searching for auto safety recall data easy and efficient. The dashboard offers user-friendly and transparent ways to sort, filter, visualize, and export recall data.



NHTSA's interactive dashboard provides improved access to vehicle recall information.

Source: NHTSA.

The dashboard, available at *https://datahub.transportation.gov/dataset/NHTSA-Recalls-by-Manufacturer/mu99-t4jn*, will be updated daily. It enables users to sort and filter data; search by keyword; and export data in CSV, TSV for Excel, XML, and other formats. It also presents data in easy-to-read charts and graphs.

Previously, NHTSA made its recall data available through a bulk download, requiring users to download large data files and import them into a database like Microsoft Access. The new dashboard makes this information easier to access and analyze.

NHTSA encourages everyone to search for open recalls by using NHTSA's VIN Look-Up Tool (*www.nhtsa.gov/recalls*) and to download the SaferCar app (*www.nhtsa.gov/campaign/safercar-app*) to stay informed on current recalls. Make sure to promptly address any open recalls.

Arizona DOT Works to Preserve Rare Cactus

The Arizona Department of Transportation (ADOT) is helping to relocate a rare and endangered species of cactus growing near the Pinto Creek bridge replacement project along U.S. 60 near Globe-Miami. The project is expected to wrap up in 2022.

Initiated in 2018, this relocation effort is the latest step in a long-term partnership between ADOT and the Desert Botanical Garden in Phoenix, AZ, to protect the hedgehog cactuses that only grow in one tiny area of the State.

ADOT is helping to preserve the endangered hedgehog cactus.

© Arizona DOT.

The rescue effort required botanists to rappel into the canyon and carefully dig up, cover, and transport the plants to the botanical garden's complex in Phoenix. There, the botanists will care for the cactuses and breed them so there are more of them when returned to the Pinto Creek Bridge site in a few years.

In June, a wildfire burned the area near the Pinto Creek bridge project. The project itself was undamaged, but many cacti were burned in the fire. ADOT's partnership with the Desert Botanical Garden to rescue, preserve, and propagate more of the cacti at the garden in Phoenix will help ensure the continued survival of the species.

Visit *https://azdot.gov/adot-blog/redoing-bridge-saving-endangered-cactus-pinto-creek* for more information.

ADOT

Technical News

INDOT Partners with Purdue to Develop Innovative Highway Infrastructure

The Indiana Department of Transportation (INDOT) and Purdue University recently announced plans to develop the world's first highway segment paved with contactless wireless-charging concrete. The project will use innovative magnetizable concrete, developed by a German startup, that enables wireless charging of electric vehicles as they drive.

Indiana is working to develop an innovative highway that can wirelessly charge electric vehicles that drive on it.

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The project is part of the Advancing Sustainability through Power Infrastructure for Road Electrification (ASPIRE) initiative, an Engineering Research Center funded by the National Science Foundation, and involves the collaboration of universities, government laboratories, businesses, and other stakeholders developing next-generation charging technologies for the electrification of transportation vehicles of all classes.

The project will include three phases. Phases 1 and 2 will feature pavement testing, analysis, and optimization research conducted by the Joint Transportation Research Program at Purdue's West Lafayette campus. In phase 3, INDOT will construct a quarter-mile-long testbed at a location yet to be determined, where engineers will test the innovative concrete's capacity to charge heavy trucks operating at high power (200 kilowatts and above). Upon the successful completion of testing of all three phases, INDOT will use the new technology to electrify a yet-to-be-determined segment of interstate highway within Indiana.

INDOT

NCDOT Pilots New Commercial Trucking Alert System

The North Carolina Department of Transportation (NCDOT) is taking a novel approach to reducing the risk of commercial truck crashes to help keep work zones and highways flowing smoothly. The department is partnering with a Canada-based company that provides innovative connected-truck technology, including in-cab communications. The in-truck messaging provides real-time alerts of urgent road conditions. The alerts will help commercial drivers react more quickly before encountering stopped traffic or major slowdowns.

"We want drivers to have every tool and technological advancement necessary to reach their destination safely and efficiently," says Beau Memory, NCDOT's chief operating officer. "This collaboration demonstrates our commitment to driver safety with technology that could become an invaluable tool for transportation."

The first-in-the-Nation pilot covers all 182 miles (293 kilometers) of I–95 and the rural portions of I–40. The safety alerts under the pilot can reach commercial drivers even where there are no digital signs to provide traffic updates. The alerts have messages such as "Sudden Slowdown Ahead" and "Congestion Ahead" about 2 or 3 miles (3 to 5 kilometers) before commercial truck drivers encounter the slowed traffic or incident.

Big rigs need more time to slow down, and crashes involving tractor-trailers can close highways for extended periods and contribute to secondary crashes, such as rear-end collisions. A fully loaded tractor-trailer traveling at 65 miles (105 kilometers) per hour takes 66 percent longer to stop than a passenger car, according to the trucking industry.

The 1-year contract to employ the alerts began on May 17, 2021. After the pilot period, NCDOT will evaluate the safety benefits of the pilot.

NCDOT

A pilot program in North Carolina is exploring in-cab alert messaging to provide traffic updates to commercial truck drivers.

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Scaling Probabilistic Risk-Based Estimating to Project Size

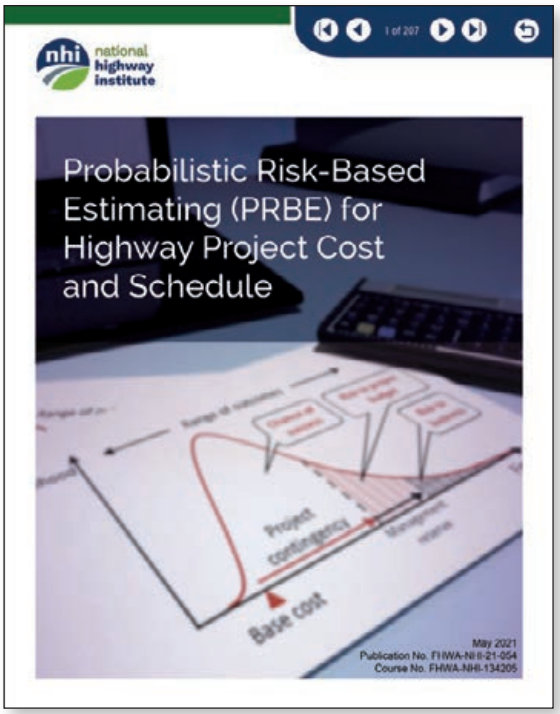
by **GAY DUGAN** and **CHRISTINE KEMKER**

How much is an accurate cost and schedule estimate worth? Accurately estimating project cost has been a challenge for decades. The National Highway Institute's new eBook training, *Probabilistic Risk-Based Estimating (PRBE) for Highway Project Cost and Schedule* (FHWA-NHI-134205), aims to provide participants with the knowledge and tools needed address this challenge. This self-paced training introduces fundamental concepts and recommended processes to successfully implement PRBE procedures within any organization.

The PRBE process, which can help reduce cost overruns, is an evolution from traditional project estimates that rely on historical data from similar projects. Instead, PRBE provides a framework to assess project risks to cost and schedule objectives. This provides agencies more certainty in funding projects and setting completion dates. Although FHWA and several States are successfully implementing PRBE, this course is the first time the PRBE concepts and process have been put into a training format.

"Project estimates often have a lot of uncertainty, especially in the early stages of project development," says Michael Smith, a project management engineer in FHWA's Resource Center in the Office of Innovation Implementation. "PRBE is a process that exposes areas of uncertainty and provides the project manager a reliability-based estimate of cost and schedule completion while identifying significant project risks."

For States that use an enterprise risk management framework, PRBE can be another tool for implementing risk management. It applies the risk framework at the project level to cost estimates. With an appropriate level of effort, scaled to the size and complexity of the project, State and local agencies can benefit from the application of the PRBE process.



NHI's new eBook training course is a self-paced, interactive PDF that learners can download on any device to study.

Source: FHWA.

Source: FHWA.

In addition to achieving improved reliability, users will benefit from earlier understanding of the project and its associated risks; enhanced ability to set achievable budgets and schedules; better control of costs to optimize budgets; more useful, credible ways to manage budgets and communicate risks to the public and stakeholders; and enhanced collaboration to achieve project objectives.

"The objective of this eBook course is to provide awareness of PRBE," says Smith. "Our goal is to give State departments of transportation the knowledge and tools they need to implement the PRBE process, to be able to deliver more projects within budget and on time."

What is an eBook training?

An NHI first, this eBook training is designed to be both interactive and independent. The course is built as an interactive PDF, with expandable graphics, check-in questions that provide feedback, job-related questions, terminology popups, and a case study embedded throughout. Learners can take notes and answer questions directly in the PDF. It also remains a resource reference after the training is complete.

As an eBook, this training can be downloaded and taken at the learner's leisure, minimizing disruption to regular work schedules. Once downloaded, it can be accessed from any device, and all the interactive features are present even if the device is not connected to the internet. Learners only need to log back into NHI's My Training site to take the exam after reading the eBook.

Taking the Course

The course can be found at *https://bit.ly/NHI_134205* and it costs $50 to register and download the eBook. This eBook is an intermediate-level course. Transportation professionals interested in this PRBE training should have some familiarity with the American Association of State Highway and Transportation Officials' *Practical Guide for Cost Estimation* or experience with cost estimation, project management, and/or risk management. NHI estimates that reading the eBook will take 10 hours of active study time. Participants who successfully complete the course will earn one continuing education credit.

What's next?

Starting next year, FHWA will offer free onsite PRBE training that includes an application tool to implement the process. Interested participants should reach out to their local FHWA division office for more information after passing this eBook training.

GAY DUGAN is the training program manager for this course with the FHWA Office of Innovation Management, Education, and Partnership - NHI.

CHRISTINE KEMKER is a contracted marketing analyst for FHWA NHI.

COMMUNICATION PRODUCT UPDATES

Below are brief descriptions of communications products recently developed by the Federal Highway Administration's Office of Research, Development, and Technology. All of the reports are or will soon be available from the National Technical Information Service (NTIS). In some cases, limited copies of the communications products are available from FHWA's Research and Technology (R&T) Product Distribution Center (PDC).

Compiled by **LISA A. SHULER** of FHWA's Office of Corporate Research, Technology, and Innovation Management

When ordering from NTIS, include the NTIS publication number (PB number) and the publication title. You also may visit the NTIS website at *www.ntis.gov* to order publications online. Call NTIS for current prices. For customers outside the United States, Canada, and Mexico, the cost is usually double the listed price. Address requests to:

National Technical Information Service
5301 Shawnee Road
Alexandria, VA 22312
Telephone: 703–605–6050
Toll-free number: 1–888–584–8332
Website: www.ntis.gov
Email: customerservice@ntis.gov

Requests for items available from the R&T Product Distribution Center should be addressed to:

R&T Product Distribution Center
Szanca Solutions/FHWA PDC
700 North 3rd Avenue
Altoona, PA 16601
Telephone: 814–239–1160
Fax: 814–239–2156
Email: report.center@dot.gov

For more information on R&T communications products available from FHWA, visit FHWA's website at *www.fhwa.dot.gov*, the FHWA Research Library at *https://highways.dot.gov/resources/research-library/federal-highway-administration-research-library* (or email *fhwalibrary@dot.gov*), or the National Transportation Library at *ntl.bts.gov* (or email *library@dot.gov*).

Developing Crash Modification Factors for Adaptive Signal Control Technologies

Publication Number: FHWA-HRT-20-072 (Report) and FHWA-HRT-20-073 (TechBrief)

Adaptive signal control technologies (ASCTs)—using traffic sensor systems to measure traffic conditions in a corridor—can alter traffic signal timing in real time. They enable a better distribution of signal green time that reduces delay and traffic congestion. Research has found that ASCTs reduce fuel consumption, emissions, and air pollution; prioritize public transport and emergency vehicles; and improve accommodation of roadwork and special events traffic.

As part of FHWA's Development of Crash Modification Factors Program, members of the technical advisory committee for the Evaluations of Low-Cost Safety Improvements Pooled Fund Study conducted a project evaluating the safety effectiveness of ASCTs at urban intersections. This study looked at how the implementation of ASCTs impacted safety improvements through a crash-based evaluation. For this study, the researchers collected and analyzed crash data for traffic intersections with ASCT installations from three States: Florida, Texas, and Virginia. The project team also conducted an economic cost/benefit analysis of installing ASCTs at traffic intersections in those three States.

The report is available at *www.fhwa.dot.gov/publications/research/safety/20072/20072.pdf*. The TechBrief is available at *www.fhwa.dot.gov/publications/research/safety/20073/index.cfm*.

Effective Indicators of Partially Automated Truck Platooning

Publication Number: FHWA-HRT-21-016

As automated trucking technology continues to develop rapidly, full-scale commercial deployment of partially automated truck platoons (two to four cooperative adaptive cruise control-equipped trucks that follow each other closely over long trips) on public roads is on the horizon. Establishing positive interactions between these truck platoons and other vehicles is crucial to the continuing implementation of automated driving technologies. To help facilitate these safe interactions and increase road user understanding of truck platooning operations, a team of researchers conducted experiments for developing effective novel signage on roadways.

The project team conducted two experiments. The first experiment surveyed a group of drivers' feelings toward, and behavior around, trucks (conventionally driven and partially automated) on the road. They also surveyed how certain novel signs might

influence these drivers' feelings and behavior. The second experiment had a different group of participants examine and answer questions related to scenarios with two truck platoons, evaluating how novel signs could impact these participants' judgment around platoons on roadways.

The TechBrief is available at *www.fhwa.dot.gov/publications/research/safety/21016/index.cfm*.

Statistical Analysis of Pavement Profiler Data to Evaluate the Bump at the End of the Bridge

Publication Number: FHWA-HRT-21-037

The bump at the end of the bridge (BEB) remains a chronic problem for the Nation's roadway bridges. Occurring at the point of transition onto and off the bridge deck, the BEB can cause many problems, including user discomfort and safety concerns, vehicle damage, and increased maintenance. The occurrence of the BEB is often related to bridge and approach roadway design and construction processes, but factors like pavement or deck roughness at bridge approaches are often not quantified.

This study aimed to quantify the magnitude and roughness of the BEB on various bridges throughout the United States by evaluating results collected from high-speed inertial profilers. The researchers also employed statistical analysis of these BEB data to analyze the effects of different site and bridge characteristics on the magnitude and roughness of the BEB.

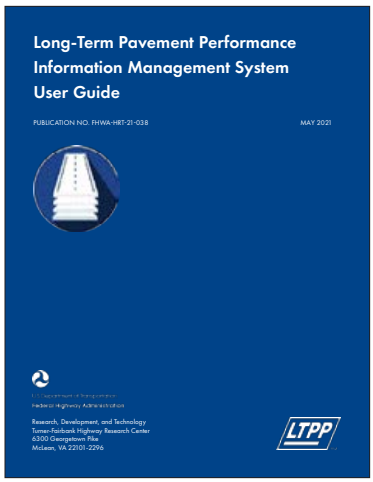
The report is available at *www.fhwa.dot.gov/publications/research/infrastructure/structures/bridge/21037/index.cfm*.

Long-Term Pavement Performance Information Management System User Guide

Publication Number: FHWA-HRT-21-038

Existing for more than three decades, FHWA's Long Term Pavement Performance (LTPP) program has become an important database for pavement performance research.

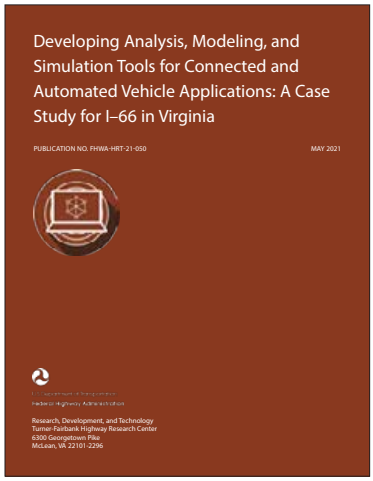
This document provides an overview of the LTPP's Information Management System (IMS). It gives an overview of the three main parts of the IMS: products (for example, research findings and new software tools), the Pavement Performance Database, and the Ancillary Information Management System. The various database modules for specific types of data tables are also outlined, including administration, automated weather station, climate, and Modern-Era Retrospective Analysis for Research and Applications (MERRA) modules.



The report is available at *www.fhwa.dot.gov/publications/research/infrastructure/pavements/21038/index.cfm*.

Developing Analysis, Modeling, and Simulation Tools for Connected and Automated Vehicle Applications: A Case Study for I–66 in Virginia

Publication Number: FHWA-HRT-21-050



FHWA continues to support research related to connected and automated vehicles (CAVs), sponsoring three case studies examining the impact of CAVs on traffic and energy, and the applications of CAV and traffic management strategies on various freeway and arterial corridors. In this case study, the researchers investigated the effectiveness of certain CAV applications (platooning, speed harmonization, and cooperative merge) in mitigating traffic congestion. The research team used roadway simulations on a 13-mile (21-kilometer) strip of I–66 in northern Virginia. The project team also looked at the potential benefits of dedicated ramps and a realistic managed-lane concept.

The report is available at *www.fhwa.dot.gov/publications/research/operations/21050/21050.pdf*.

FHWA's TRANSPORTATION POOLED FUND PROGRAM

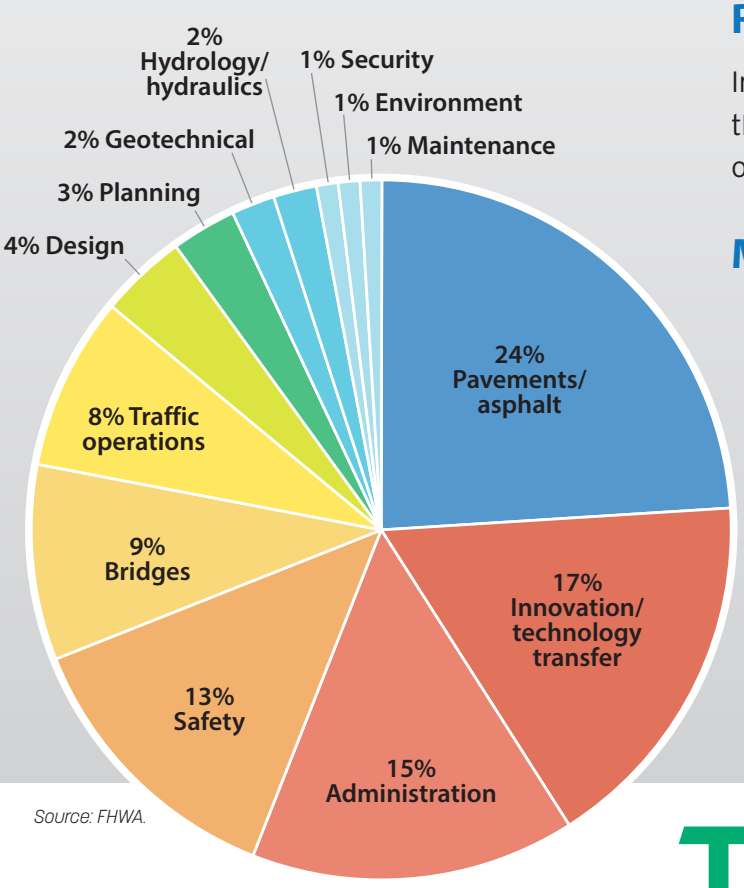
Leveraging resources to achieve common research goals

The Transportation Pooled Fund (TPF) Program enables public and private entities to combine resources to conduct high priority research on a wide variety of shared, highway related problems. Over more than 20 years, the TPF Program has supported more than 750 successful multi-State projects.

© Colorado Department of Transportation.

Leverage Expertise Across the Country

By participating on the technical advisory committees of TPF studies, partners are able to form connections with peers in other States to share subject matter expertise across the country.



Source: FHWA.

Participate in Diverse Research and Topic Areas

Investing in TPF studies helps partners stretch their research dollars to support a diverse array of topic areas.

Make an Impact Through a TPF Study!

The TPF Program is a great resource to leverage limited funds to address important transportation issues. Learn more about initiating a pooled fund study and browse the list of open solicitations on the TPF website at ***www.pooledfund.org***.

For more information, contact Tricia Sergeson, TPF Program Manager, at ***Patricia.Sergeson@dot.gov***.

TPF TRANSPORTATION POOLED FUND

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Introducing the

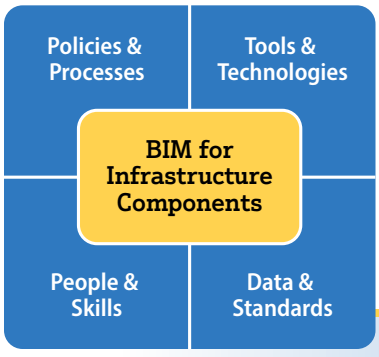
Building Information Modeling (BIM) for Infrastructure National Strategic Roadmap

The **BIM for Infrastructure National Strategic Roadmap** is a framework and path to help highway agencies strategically develop:

- A uniform, nationwide policy related to BIM for Infrastructure
- Open data exchange standards and methods for adopting those standards
- A robust personnel training program

Using the roadmap, FHWA proposes to collaborate on a shared vision, goal, and objective for BIM:

- The ***vision*** is to digitalize project delivery, operations, and maintenance for the Nation's highway infrastructure and make information available to anyone who needs it, when they need it.
- The ***goal*** is for State departments of transportation to adopt BIM for Infrastructure practices.
- The ***objective*** is for FHWA and State DOTs to develop and implement a set of activities to incentivize achieving progressively higher degrees of BIM maturity over time.



Source: FHWA.

Pooled fund TPF-5(480) provides an opportunity for collaboration on BIM Roadmap activities and is still open for additional participants.

For more information, visit **www.fhwa.dot.gov/publications/research/infrastructure/pavements/21064/index.cfm**.

United States Postal Service Statement of Ownership, Management, and Circulation

1. Publication Title: Public Roads
2. Publication Number: 0033-3735
3. Filing Date: August 4, 2021
4. Issue Frequency: Quarterly
5. Number of Issues Published Annually: Four
6. Annual Subscription Price: $21.00 (Domestic), $29.40 (Foreign)
7. Complete mailing address of known office of publication:

   Federal Highway Administration,
   6300 Georgetown Pike, Room T-301,
   McLean, VA 22101
8. Complete mailing address of headquarters or general business office of publisher:

   Federal Highway Administration,
   1200 New Jersey Avenue, SE,
   Washington, DC 20590
9. Full names and complete mailing addresses of publisher, editor, and managing editor:

   Publisher: Federal Highway Administration,
   1200 New Jersey Avenue, SE,
   Washington, DC 20590

   Editor: Carrie Boris, ICF,
   9300 Lee Highway, Fairfax, VA 22031

   Managing Editor: Caroline Ibarra,
   Arch Street Communications,
   31 Mamaroneck Avenue, White Plains, NY 10601
10. Owner: U.S. Department of Transportation,
    1200 New Jersey Avenue, SE,
    Washington, DC 20590
11. Known bondholders, mortgagees, and other security holders owning or holding 1 percent or more of total amount of bonds, mortgages, or other securities: N/A
    U.S. Government Publication
12. Tax Status: Has not changed during preceding 12 months
13. Publication Title: Public Roads
14. Issue Date for Circulation Data Below: Summer 2021
15. Extent and Nature of Circulation
    A. Total Number of Copies (Net press run):

       Average no. copies each issue during preceding 12 months: 2,000

       No. copies of single issue published nearest to filing date: 2,000

    B. Paid Circulation (By Mail and Outside the Mail)

       (1) Mailed Outside-County Paid Subscriptions Stated on PS Form 3541 (Include paid distribution above nominal rate, advertiser's proof copies, and exchange copies)

       Average no. copies each issue during preceding 12 months: 0

       No. copies of single issue published nearest to filing date: 0

       (2) Mailed In-County Paid Subscriptions Stated on PS Form 3541 (Include paid distribution above nominal rate, advertiser's proof copies, and exchange copies)

       Average no. copies each issue during preceding 12 months: 0

       No. copies of single issue published nearest to filing date: 0

       (3) Paid Distribution Outside the Mails Including Sales Through Dealers and Carriers, Street Vendors, Counter Sales, and Other Paid Distribution Outside USPS®

       Average no. copies each issue during preceding 12 months: 1,771

       No. copies of single issue published nearest to filing date: 1,779

       (4) Paid Distribution by Other Classes of Mail Through the USPS (e.g., First-Class Mail®)

       Average no. copies each issue during preceding 12 months: 229

       No. copies of single issue published nearest to filing date: 221

    C. Total Paid Distribution:

       Average no. copies each issue during preceding 12 months: 2,000

       No. copies of single issue published nearest to filing date: 2,000

    D. Free or Nominal Rate Distribution (By Mail and Outside the Mail):

       (1) Free or Nominal Rate Outside-County Copies Included on PS Form 3541

       Average no. copies each issue during preceding 12 months: 0

       No. copies of single issue published nearest to filing date: 0

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       Average no. copies each issue during preceding 12 months: 0

       No. copies of single issue published nearest to filing date: 0

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       Average no. copies each issue during preceding 12 months: 0

       No. copies of single issue published nearest to filing date: 0

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       Average no. copies each issue during preceding 12 months: 0

       No. copies of single issue published nearest to filing date: 0

    E. Total Free or Nominal Rate Distribution:

       Average no. copies each issue during preceding 12 months: 0

       No. copies of single issue published nearest to filing date: 0

    F. Total Distribution:

       Average no. copies each issue during preceding 12 months: 2,000

       No. copies of single issue published nearest to filing date: 2,000

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       Average no. copies each issue during preceding 12 months: 0

       No. copies of single issue published nearest to filing date: 0

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       Average no. copies each issue during preceding 12 months: 2,000

       No. copies of single issue published nearest to filing date: 2,000

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       Average no. copies each issue during preceding 12 months: 100%

       No. copies of single issue published nearest to filing date: 100%
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    A. Paid Electronic Copies:

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Maria Romstedt, Editor-in-Chief August 4, 2021

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