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U.S. Department of Transportation
Federal Highway Administration

Frederick "Bud" Wright Reflects on His Career

Public Roads

—featuring developments in Federal highway policies, programs, and research and technology—

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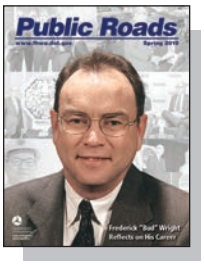

Front Cover—Former FHWA Executive Director Frederick "Bud" Wright leaves a legacy for his decades-long work in transportation. Clockwise from top left, Wright jokes with staff—and his cardboard cut-out—during his retirement party in 2018. Wright speaks to American Association of State Highway and Transportation Officials (AASHTO) staff and attendees at a NASCAR reception in 2014. Wright talks with a journalist during the AASHTO 2014 Annual Meeting. Wright delivers remarks from the podium during the 2014 Annual Meeting. Wright is featured in the video, "AASHTO Displays Orange to Support Highway Workers and Promote Work Zone Safety" in 2016. Wright poses in front of an AASHTO 100th anniversary display at the Washington Briefing event in 2014. For more information, see "A Conversation With Frederick 'Bud' Wright" on page 10 in this issue of PUBLIC ROADS. *Main photo: FHWA; Secondary photos: AASHTO.*

Back Cover—Researchers use FHWA's in situ scour testing device near a bridge in Kansas as part of their technology readiness level (TRL) assessment. TRLs can help FHWA teams determine a technology's maturity level and identify next steps for a research project. For more information, see "Measuring Maturity" on page 21 in this issue of PUBLIC ROADS. *Photo: FHWA.*

U.S. Department of Transportation
Federal Highway Administration

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

Guest Editorial

Using Technology to Spring Forward

Each spring, everything seems alive with possibility, and nowhere is that more evident than at the Federal Highway Administration. Notably, we are at the beginning of a new era of highway safety with new and emerging technologies and tools guiding the path ahead.

Often the start of spring means plenty of rain and wet roadways. It is fitting that in this issue of PUBLIC ROADS we learn about FHWA's Weather-Savvy Roads initiative, which includes two innovative road weather management solutions: Pathfinder and Integrating Mobile Observations (IMO). Promoted in the fourth round of Every Day Counts, these solutions can help agencies better manage road systems and inform travelers ahead of, and during, adverse weather conditions. See "Are Your Roads Weather Savvy?" on page 16.

The future is already upon us in the form of connected vehicles and related technologies known collectively as "the Internet of Things." If FHWA researchers are correct, the road to the future is paved with wireless technology. By connecting vehicles, Global Positioning System (GPS) guidance systems, and roadside infrastructure, we can enhance the promise of roadway safety. The fatal crashes on U.S. roads in 2017 gave us 37,133 more reasons to make the development of innovative safety measures a priority. These new technologies have the potential to radically improve the safety and mobility of our transportation network—saving lives and resources.

The U.S. Department of Transportation's connected vehicle (CV) interoperability test, which brought together teams from the CV Pilot Deployment Program sites in New York City; Tampa, FL; and Wyoming, is another step toward moving connected vehicles into real-world deployment. Interoperability ensures that CVs and roadside infrastructure from different manufacturers can exchange information and use the information in a consistent manner. The testing occurred in summer 2018 and successfully demonstrated interoperability. For more information, see "Setting a Course to Interoperability" on page 4.

Seeing how one of the Nation's most rural States (Wyoming) and most populous city (New York City) are working together to test cutting-edge CV technologies is very encouraging. From America's backroads to Broadway, every part of the U.S. transportation system stands to gain from this work.

In our zeal to adopt better, more efficient, and more effective tools, we cannot afford to be overeager. We must walk before we run. A related article, "Measuring Maturity" on page 21, explores the implementation of technology readiness level (TRL) assessments. TRL assessments are an important safeguard against using trailblazing technologies before they are fully ready. FHWA published a guide in fall 2017 to help decision-makers at the State, local, and Federal levels use TRL assessments to determine whether technologies are mature enough for widespread use, or whether additional research is needed. These assessments improve research outcomes and reduce risks associated with deploying new tools.

From TRL assessments to road-weather management and connected vehicle technologies, new tools like these are helping us *spring* forward—which is a step in the right direction.

Brandye L. Hendrickson
Deputy Administrator
Federal Highway Administration

HOT TOPIC

by Emily Biondi, Anne Rowe, and Damaris Santiago

New Framework Aims to Accelerate Project Delivery

A coordinated and timely process for environmental reviews of major infrastructure projects is essential to advancing and delivering these projects to the traveling public. Executive Order 13807, Establishing Discipline and Accountability in the Environmental Review and Permitting Process for Infrastructure Projects, sets forth a new framework—known as One Federal Decision—for Federal agency cooperation on environmental review and permitting for major infrastructure projects.

The One Federal Decision approach aims to expedite Federal environmental reviews required by the National Environmental Policy Act. Federal agencies will use a single, coordinated process to develop and issue an Environmental Impact Statement (EIS) and a Record of Decision (ROD).

The goal is for Federal agencies to complete the environmental review process for major infrastructure projects in an average of 2 years—from publication of the Notice of Intent to issuance of the ROD and all other Federal authorizations within 90 days of the ROD.

The Federal Highway Administration supports accelerated project delivery and will continue to do so through the One Federal Decision framework. In the spirit of interagency coordination, FHWA worked with several of its partner Federal resource agencies to develop a working agreement that outlines a general coordination process for FHWA's major infrastructure projects.

Interagency Collaboration

In April 2018, the U.S. Department of Transportation joined 11 other Federal agencies in signing a memorandum of understanding (MOU) that sets the process for implementing the One Federal Decision framework. Under the MOU, Federal agencies conduct their review processes at the same time, rather than sequentially. The agencies collaborate throughout the process and resolve any issues in a timely manner. One Federal Decision also implements the requirements for a single EIS, a single ROD, and a single administrative record.

FHWA's working agreement with partner agencies includes a coordination process chart, which synchronizes various agency activities with the goal to complete the environmental review process in 2 years. The chart identifies activities that should happen prior to the publication of the Notice of Intent and identifies the timing of the three agency concurrence points: 1) purpose and need, 2) range of alternatives to be carried forward for analysis, and 3) preferred alternative. Lead agencies will obtain written concurrence for these three points from all cooperating agencies whose authorizations are required for the project.

For more information on One Federal Decision, visit www.environment.fhwa.dot.gov/nepa/oneFederal_decision.aspx.

Emily Biondi is the director of FHWA's Office of Project Development and Environmental Review (HEPE).

Anne Rowe is the environmental protection specialist in HEPE.

Damaris Santiago is the team leader for Project Mitigation in HEPE.

Currently, FHWA is processing three projects under the One Federal Decision framework.

Active Projects

U.S. Route 58/220 Bypass to North Carolina State Line Limited-Access Study (Virginia). The Virginia Department of Transportation is evaluating potential transportation improvements along the U.S. Route 220 corridor between the U.S. Route 58/220 Bypass and the North Carolina State line, also referred to as the Martinsville Connector Study. FHWA issued the Notice of Intent in February 2018. For more information on this project, visit www.virginiadot.org/projects/salem/martinsville_southern_connector_study.asp.

I–495/I–270 Managed Lanes Study (Maryland). The Maryland State Highway Administration is evaluating alternatives to accommodate existing and future traffic, improve trip reliability, expand travel options, accommodate homeland security, and improve the movement of goods and services within the study limits. FHWA issued the Notice of Intent in March 2018. For more information on this project, visit https://495-270-p3.com.

Tri-County Access Study (Illinois). The Illinois Department of Transportation, in collaboration with the Illinois Tollway, is conducting a comprehensive regional study to identify environmentally and fiscally responsible solutions to regional traffic congestion in Lake, northern Cook, and eastern McHenry counties. FHWA issued the Notice of Intent in July 2018. More information on this project is available at http://tricountyaccess.org.

by Peter Mancauskas

Flexible Financing for Small Communities

Decreasing resources and increasing demands require Federal and State transportation agencies to explore innovative financing tools for infrastructure projects. State infrastructure banks (SIBs) are one such tool. Compared to relying entirely on grant-based financing, SIBs can offer accelerated project delivery, provide lower borrowing costs, and facilitate completion of financial plans.

"A federally funded SIB, much like a private bank, can offer a range of loans and credit enhancement products to public and private sponsors of highway, transit, or rail projects," says Mark Sullivan, director of the Federal Highway Administration's Center for Innovative Finance Support. As transportation agencies repay loans or other forms of credit assistance to the SIB, the bank's initial capital is replenished to support a new cycle of projects.

Initially established by the National Highway System Designation Act of 1995, Federal SIBs are now active in 29 States. They have provided more than 950 loans for a total of more than $3.1 billion to fund transportation projects throughout the country. In addition, several States have established separate SIBs with State funds.

FHWA is looking to expand lending through the SIB program, especially in smaller communities where it can be more difficult to secure the required funding for transportation projects. This has become more important now than in the past, as gas tax revenues have not kept pace with the demands on the transportation system.

The Advantage of Flexibility

By offering low interest rates and negotiable repayment terms, an SIB provides a low-cost option for capital funds to a wide range of project sponsors.

For example, Missouri has sponsored two innovative methods to use its SIB. Through the Missouri Department of Transportation's Cost Share Program, which builds partnerships with local entities to pool efforts and resources to deliver State highway and bridge projects, local governments use SIB loans to fund their share of the project costs. Missouri also uses SIB loans to accelerate payments of the State's share of project costs that may be programmed in future years. In these loan agreements, local entities are responsible only for interest payments, while the State makes the principal payments.

In Texas, the most common SIB loans are local governments borrowing for utility relocations on roadway projects. This type of loan provides valuable assistance, financing the costs that cities and towns are solely responsible for and enabling municipal projects to move forward sooner than they could with traditional funding options.

Looking Ahead

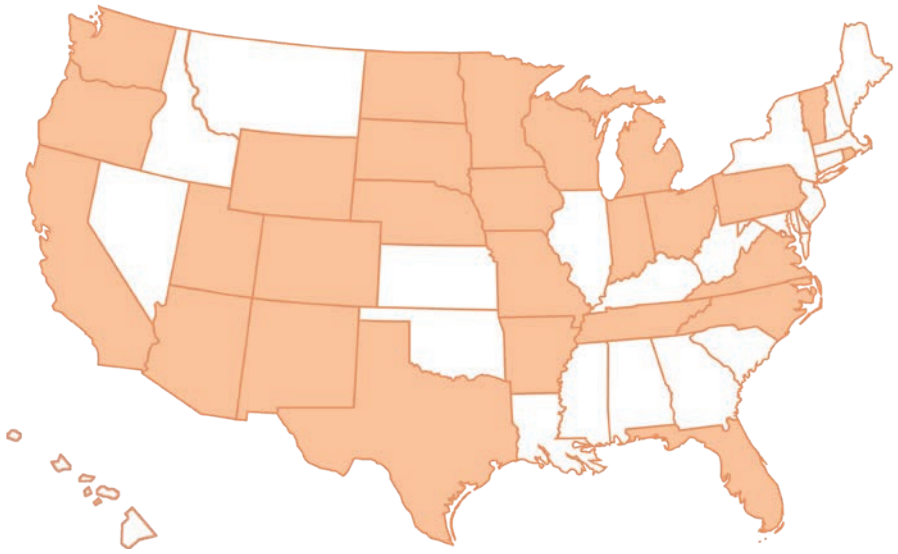
FHWA's Center for Innovative Finance Support recently conducted a series of roundtables and an informal survey with its partners to determine what additional assistance the SIB program could provide. Many participants responded that the program could benefit from marketing assistance, specifically to local and rural borrowers.

As a result of the feedback, the center is developing marketing and training tools for a lending opportunity that rural and smaller communities can benefit from called Local Innovative Match Assistance (LIMA). With this funding initiative, local sponsors of Federal-aid projects can directly finance their non-Federal share through the SIB program where available. LIMA provides them with access to at- or below-market-rate loans and eliminates the burden on rural and small communities of having to secure the funds necessary for a required local match for federally funded projects.

For more information, contact Peter Mancauskas at Peter.Mancauskas@dot.gov.

Peter Mancauskas is the project finance program manager at FHWA's Center for Innovative Finance Support, Office of Innovative Program Delivery.

Current Federal SIBs



(not shown: Alaska, District of Columbia, and Puerto Rico)

Source: Center for Innovative Finance Support, FHWA.

Setting a Course to Interoperability

by Kate Hartman, Deborah Curtis, Edward Fok, and Govindarajan Vadakpat

USDOT successfully demonstrated the ability to operate connected vehicles cross-site, over-the-air among six participating vendors from three pilot sites.

A connected vehicle equipped with an onboard unit receives a forward collision warning alert from a stationary vehicle in the same lane of a controlled test track during the USDOT interoperability test at the Turner-Fairbank Highway Research Center in McLean, VA. *Photo: USDOT.*

Connected vehicles have the potential to transform travel in the United States, helping to save lives, improve personal mobility, enhance economic productivity, and transform public agency operations. The U.S. Department of Transportation is leading research to move connected vehicles closer to wide-scale, national deployment.

To pave the way, one of USDOT's major goals is to test and demonstrate the current level of interoperability among still-maturing connected vehicle technologies. Interoperability ensures that devices including onboard units (devices installed in vehicles) and roadside units (devices deployed along the roadside by State and local agencies) from different manufacturers can exchange data and use the data in a consistent manner.

A watershed moment in the maturation of connected vehicles occurred at the Federal Highway Administration's Turner-Fairbank Highway Research Center (TFHRC) in June 2018. Through a collaborative effort, USDOT and three demonstration sites from the Connected Vehicle (CV) Pilot Deployment Program conducted an interoperability test. The test was the first of its kind involving devices from three deployment sites and six device vendors.

The goal of the test was to demonstrate whether onboard units installed in vehicles—and manufactured by different companies—from one CV pilot demonstration site could send and receive messages from onboard units and roadside units from other sites. More specifically, it looked at whether it is possible to send and receive messages between devices from different CV pilot sites in accordance with the key connected vehicle interfaces and standards.

Working with USDOT and its contractors, the CV pilot sites—New York City; Tampa, FL; and Wyoming—collaborated to harmonize the data elements and electronic messages that would be exchanged to make such interactions possible. This involved agreeing on a common set of data standards and establishing the security profiles, message protocol, and interpretations to enable converting the data being exchanged into the formats required for the various devices.

The interoperability test was the result of planning and collaboration facilitated through a series of biweekly technical roundtable meetings over the 6-month period leading up to the event. Coming into the test, participants were eager to see if all the preparation would pay off—and it did.

In total, USDOT and the CV pilot sites conducted more than 100 interoperability test runs for four test application-based cases—(1) forward collision warning, (2) intersection movement assist, (3) emergency electronic brake lights, and (4) reception of vehicle-to-infrastructure (V2I) signal phase and timing (SPaT) and MAP (mobile application part) messages to support red light violation warnings. Based on the testing, USDOT concluded that all vendors and CV pilot site deployment configurations are interoperable and can trigger warnings on each other's devices.

"Innovative testing like this helps provide confidence in the value of connectivity and that connected technologies will be interoperable nationwide," says Bob Frey, director of planning and innovation at the Tampa Hillsborough Expressway Authority (THEA), which is leading the Tampa CV pilot deployment. "The testing proved that when standards are implemented correctly—from the beginning, even with a new technology—the ability for multiple manufacturers to successfully cooperate to provide a safer, more efficient road system for the public is possible."

Tested Applications

Application	Description
Forward Collision Warning	An application where alerts are presented to the driver to help avoid or mitigate the severity of crashes into the rear end of other vehicles on the road. Forward collision warning responds to a direct and imminent threat ahead of the host vehicle.
Emergency Electronic Brake Lights	An application where the driver is alerted to hard braking in the traffic stream ahead. This provides the driver with additional time to look for and assess situations developing ahead.
Intersection Movement Assist	An application that warns the driver when it is not safe to enter an intersection—for example, when something is blocking the driver's view of opposing or crossing traffic. This application only functions when the involved vehicles are all vehicle-to-vehicle (V2V)-equipped.
Red Light Violation Warning	An application that broadcasts signal phase and timing (SPaT) and other data to the invehicle device, enabling warnings for impending red light violations.

The Connected Vehicle Pilot Deployment Program

USDOT and its partners are working with State and local agencies to accelerate the deployment of this emerging technology, demonstrate its potential benefits, and help to overcome potential barriers and challenges along the way.

USDOT launched the CV Pilot Deployment Program in September 2015 to deploy, test, and operationalize cutting-edge mobile and roadside technologies and to enable multiple CV applications. Sponsored by the Intelligent Transportation Systems (ITS) Joint Program Office (JPO), USDOT awarded cooperative agreements to three agencies: the New York City Department of Transportation (NYCDOT), THEA, and the Wyoming Department of Transportation.

A THEA vehicle (white car) drives in an adjacent lane on a controlled test track at TFHRC without triggering a forward collision warning alert from a stationary NYCDOT vehicle. *Photo: USDOT.*

During the first phase of the program, which lasted 12 months (September 2015 to August 2016), each site prepared a comprehensive deployment plan to address all of the proposed and other applications, security, operation and maintenance, procurement, and testing. In phase two (fall 2016 to spring 2019), the three sites designed, built, and tested the Nation's most complex and extensive deployment of integrated wireless invehicle, mobile device, and roadside technologies. In the third and current phase, the CV pilot sites are operating and maintaining their pilot deployment, assessing impacts, and evaluating deployment performance.

While each CV pilot site set out to address its specific local needs, the sites also have been working with USDOT to develop interoperable CV devices, equipment, and software that leverage industry standards.

Connected Vehicle Pilot Deployment Sites

New York City. The New York City pilot aims to improve the safety of travelers and pedestrians in the city through the deployment of V2V and V2I technologies. This objective directly aligns with the city's Vision Zero initiative, which seeks to reduce the number of fatalities and injuries resulting from traffic crashes.

New York City's deployment provides an ideal opportunity to evaluate connected vehicles and applications in tightly spaced intersections typical in a dense urban transportation system. It is set to be the largest CV deployment to date. The deployment will equip approximately 3,000 cabs, 700 Metropolitan Transportation Authority buses, 170 NYC Sanitation fleet delivery trucks, and more than 3,000 city-owned vehicles. In addition, approximately 340 signalized intersections are equipped with V2I technology. As a city bustling with pedestrians, the pilot also focuses on reducing vehicle-pedestrian conflicts through invehicle pedestrian warnings and an additional V2I/I2V project component that equips approximately 100 pedestrians with personal devices that assist them in safely crossing the street. For more information, visit https://cvp.nyc.

THEA. Tampa Hillsborough Expressway Authority (THEA) owns and operates the Selmon Expressway Reversible Express Lanes. The THEA pilot will deploy a variety of V2V and V2I applications to relieve congestion, reduce collisions, and prevent wrong way entry at the reversible express lanes' exit. THEA also plans to use CV technology to enhance pedestrian safety, speed up bus operations, and reduce conflicts between street cars, pedestrians, and passenger cars at locations with high volumes of mixed traffic.

The THEA CV Pilot will employ dedicated short-range communications (DSRC) to enable transmissions among approximately 1,600 cars, 10 buses, 10 trolleys, 500 pedestrians with smartphone applications, and approximately 40 roadside units along city streets. For more information, visit www.tampacvpilot.com.

Wyoming. Interstate 80 (I–80) in southern Wyoming is a major corridor for east-west freight movement, moving more than 32 million tons of freight per year. During winter seasons when wind speeds and wind gusts exceed 30 miles per hour (48 kilometers per hour) and 65 miles per hour (105 kilometers per hour) respectively, crash rates on I–80 can be 3 to 5 times as high as summer crash rates. This resulted in 200 truck blowovers and numerous road closures within 4 years.

The Wyoming CV pilot focuses on the needs of commercial vehicle operators and will develop applications that use V2I and V2V connectivity to support a flexible range of services such as advisories including roadside alerts, parking notifications, and dynamic travel guidance. The deployment is expected to reduce the number of blowover incidents and adverse weather-related incidents along the corridor to improve safety and reduce incident-related delays. The demonstration will include 75 roadside units that can receive and broadcast messages and approximately 400 vehicles consisting of a combination of fleet vehicles and commercial trucks with onboard units. For more information, visit https://wydotcvp.wyoroad.info.

USDOT has a website with free CV resources for States, local agencies, and the public. The CV pilots' portal contains prerecorded webinars, presentations, and detail documents from each CV pilot site, for both phase 1 and phase 2 of the project. Resources range from the concept of operations, the safety management plan, and the system requirements specification to the application deployment plan and much more. In addition, the CV pilots' portal has a subsection focused on success stories and lessons learned. The portal is available at www.its.dot.gov/pilots.

What Is Interoperability?

Industry ITS standards support interoperability, which enables vehicles and the roadside infrastructure to exchange data in a consistent manner, regardless of the manufacturer of the vehicle, onboard unit, or roadside unit. Dozens of communities across the country are currently deploying or planning to deploy roadside units to enable data sharing and to support electronic message exchanges with vehicles. All elements in a CV environment—including onboard units, roadside units, and other ITS devices—must work together in a safe, trusted, interoperable, and efficient manner.

Adhering to ITS standards enables devices installed in vehicles from one manufacturer to communicate with other vehicles that may include devices from another manufacturer. From a practical perspective, interoperability ensures drivers using CVs have a safe, consistent experience from region to region—and eventually from coast to coast.

In a series of USDOT-facilitated technical roundtable meetings, the three CV pilot sites settled on an approach to conduct the interoperability test. USDOT and the CV pilot sites defined interoperability as: "A vehicle with an onboard unit from one of the three CV pilot sites is able to interact with onboard units and/or roadside units from the other sites in accordance with the key connected vehicle interfaces and standards."

Planning for the Interoperability Test

With a clear definition of interoperability in place, the sites then worked with USDOT and its technical support contractor to develop a plan to conduct the interoperability test. The *Connected Vehicle Pilots Phase 2 Interoperability Test: Test Plan* (FHWA-JPO-18-691), available through USDOT's National Transportation Library, served as the official planning document for the interoperability test. The document describes the objectives, test equipment, test environment (or facility), roles and responsibilities, test preconditions, schedule, test cases, and test procedures necessary to conduct the interoperability test.

The scope of the interoperability test was to assess vehicle-to-vehicle (V2V) interactions between different sites' onboard units and V2I interactions between selected onboard units and roadside units. Onboard units (aftermarket equipment installed in the vehicles to conduct the test) included software that provided the capability to:

- Receive basic safety messages (BSMs) transmitted by each of the other sites' onboard units.
- Authenticate messages received from other vehicles' onboard units, as needed (such as when acting on the data or hearing a device for the first time).
- Parse messages (such as decoding messages to the individual data element level).
- Process messages (such as using the data as an input to applications, triggering responses according to the device's own application).

USDOT selected three common applications across the CV pilot sites to test interoperability: forward collision warning, emergency electronic brake lights, and intersection movement assist. In addition, researchers conducted a test to assess the ability of the onboard units from one CV pilot site to receive electronic messages containing the SPaT and MAP (the geometric intersection design) messages being broadcast from roadside units from another CV pilot site. New York City's onboard units and software also demonstrated the red light violation warning application.

Prior to the interoperability test, USDOT and the CV pilot sites conducted a test readiness review to evaluate key preconditions. The test readiness review ensured that all parties agreed to the test plan, all devices were available and ready for testing, all devices had been tested, and the test environment was ready to conduct the testing for each CV pilot site. USDOT reviewed progress toward test readiness during biweekly technical roundtable meetings. The test readiness review was a formal meeting where all stakeholders agreed that they were ready to show up to the test understanding their roles and responsibilities, and that all equipment was ready to support the interoperability testing efforts.

Testing

Testing occurred at TFHRC between June 26 and 28, 2018. The day before testing began served as a day of preparation and enabled the CV pilot teams to finalize installation of their devices in TFHRC-provided vehicles and configure and ensure operation of their applications and the roadside units.

Key to successful execution of the test was the support from FHWA TFHRC staff and its Saxton Transportation Operations Laboratory contractor who provided technical support to the CV pilot sites, the facility, and supporting equipment for the testing. This assistance included installing roadside units, installing onboard units from the sites in vehicles, and providing trained drivers to operate the vehicles during the interoperability test runs.

Each of the six TFHRC-provided vehicles had an onboard unit from one of the CV pilot site's vendors. In addition, the teams from the New York City and THEA sites each loaded their software on TFHRC-supplied roadside units. In total, the tests used two roadside units—both from the same vendor but with software from either New York City or THEA on a single device. All devices used for the tests were tied to the same commercial security credential management system (SCMS) and used test certificates from the SCMS to ensure trusted communication between onboard units and roadside units.

"Upon the successful conclusion of the interoperability testing with New York City and THEA, the WYDOT team developed confidence with the SCMS test certificates and messages," says Vince Garcia, geographic information system/ITS program manager at WYDOT. "We are prepared to move

A Wyoming onboard unit installed in a TFHRC vehicle. *Photo: USDOT.*

A THEA vehicle on a controlled test track at TFHRC approaches an intersection with a roadside unit. *Photo: USDOT.*

A THEA vehicle (white car) waits as it receives an intersection movement assist warning being triggered by a New York City vehicle (black car) at the TFHRC test track. *Photo: USDOT.*

forward with production enrollment and certificate use with our suite of applications used for heavy freight. These applications will help to improve safety during the blustery winters in Wyoming and along I–80 over some of the most rigorous terrain along the route."

Over 3 days, the teams conducted more than 100 tests at TFHRC. They collected more than 10 GB of data for all tests and then sent the data to the cloud-based system—the Secure Data Commons (SDC)—where the data are available to support future research activities. Results of the testing indicated successful interoperable transfer of messages—BSMs, MAP, and SPaT—between the six vehicles from five different vendors. Four of the vendors used dedicated short-range communications (DSRC), and one used a combination of DSRC and satellite communications. In addition, each vendor demonstrated the successful transfer of messages between roadside units and the software installed to receive, process, and use electronic messages on each site's onboard units installed on the vehicles they will be using in their respective tests.

Lessons Learned

The team identified several valuable lessons learned from the interoperability test that may be beneficial for future testing activities.

Coordinate regularly in the months leading up to the test date. Coordination before the interoperability test enabled CV pilot sites, vendors, and stakeholders to work together, procure equipment, develop a schedule, and provide feedback. A critical facilitator for coordination was a biweekly technical roundtable. A clear definition of roles and responsibilities was important to support planning and execution of the test. Clearly identifying all roles and backups in the case of unexpected events is essential.

Coordinate with test sites to receive all equipment and software well in advance of conducting the test. The CV pilot sites shipped all testing equipment to TFHRC 2 weeks before testing. This amount of time enabled TFHRC to set up onboard units in designated vehicles and make sure the software was working as designed. It also provided time for representatives from CV pilot sites to verify the installations.

Schedule a full day for setup, checkout, and dry runs. Using the first full day to check equipment installation and ensure applications run as expected, among other things, was beneficial. CV pilot sites and vendors were able to do last-minute updates, study the test bed, and make changes to the test plan for successful execution.

Make conservative estimates for test runs. For planning purposes, the teams assumed 10 minutes per test run for the interoperability testing. However, this estimate accommodated for the test run and data collection activities. Some test runs and data collection activities took as little as 2 minutes to conduct, while others took more than 10 minutes. In general, use conservative estimates to account for variability of test runs.

Include a premeeting and set aside 20–30 minutes for dry runs before conducting individual tests. While running the individual tests, the teams found it beneficial to run through the test procedures for each application's test a few times to well inform drivers, vendors, and stakeholders and set expectations. In addition, schedule time at the end of each day to identify which tests need to be rerun and to discuss any issues the drivers and other individuals encountered during testing.

A Wyoming vehicle (on right) receives a forward collision warning alert being triggered by a New York City vehicle with the other four vehicles driving by the adjacent lane on the test track. *Photo: USDOT.*

Have walkie-talkies to communicate with drivers, test leads, USDOT representatives, and others during test runs. Walkie-talkies were indispensable during the interoperability test. USDOT representatives were able to communicate the start time of each test with invehicle personnel as well as flaggers. The test director and other staff leading coordination of the testing activities also communicated end time for each test via walkie-talkies.

Moving Forward

Overall, the 3-day testing event was a major success that went above and beyond the event's original testing objectives, with time allotted on the last day for some impromptu tests. Results of the testing indicated successful transfer of messages between the six vehicles with devices from five different onboard unit vendors. In addition, equipment from New York City's and THEA's vendors demonstrated the successful transfer of messages between the site-configured roadside units and the sites' onboard units.

For more information, a video summarizing the interoperability test is available at www.its.dot.gov/interoperabilityvideo.

The results of the interoperability test are encouraging, but State and local agencies planning to deploy CVs cannot expect out-of-the-box plug and play interoperability. However, the tests show that organizing around current standards can produce a relatively high level of interoperability. More work remains to strengthen and improve standards, as well as bring more vendors, deployers, and USDOT together to build upon this important step.

The interoperability test was a major step forward. As the CV pilot sites move into their deployment phase, and dozens of State and local agencies deploy CVs across the country, continued collaboration is necessary to ensure that the systems are interoperable so that drivers have the same experience when using devices as they travel from coast to coast.

"It is essential to demonstrate interoperability among vendors' products by applying connected vehicle standards," says Mohamad Talas, director of systems engineering at NYCDOT. "Interoperability will ensure successful expansion and sustainability of the deployment and will help New York City achieve its goal of improving safety. We are happy with the outcome of the test and hope the efforts will continue to further address more features and applications of this promising technology."

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For more information, see www.its.dot.gov/pilots/index.htm or contact Kate Hartman at 202-366-2742 or Kate.Hartman@dot.gov.

The CV pilot interoperability test included participants from USDOT and its contractors, the CV pilot sites, connected vehicle device vendors, and others. *Photo: USDOT.*

A Conversation With

Frederick "Bud" Wright

The recently retired AASHTO executive director and former FHWA executive director reflects on his 43-year career in transportation.

After more than 4 decades and multiple leadership roles in the field of transportation, Frederick G. "Bud" Wright has valuable insights into the industry. Wright had a distinguished career at the Federal Highway Administration, serving as executive director from 2001 to 2008—the first non-engineer to hold the position. As executive director, he managed the daily operations of the agency and its personnel, while advising the administrator, deputy administrator, and senior U.S. Department of Transportation officials.

Wright's earlier leadership positions with FHWA included program manager for safety, director of the Office of Budget and Finance, and administrator of the Nevada Division Office. During his FHWA career, Wright received the Presidential Rank Award, the U.S. Secretary of Transportation's Special Achievement Award, the Federal Highway Administrator's Superior Achievement Award, and the Secretary of Transportation's Team Award for development of the Transportation Equity Act for the 21st Century.

Beginning in 2012, Wright spent 6 years as executive director of the American Association of State Highway and Transportation Officials (AASHTO). His retirement at the end of 2018 prompted FHWA's current Executive Director, Thomas D. Everett, to interview Wright about his unique perspective on the two organizations, the challenges they face, the relationship between FHWA and the States, and other transportation issues. What follows are excerpts from their discussion.

Everett: Looking back on your time as executive director of FHWA, what were the top challenges you faced, and what did you take away from each experience?

Wright: I always thought the hardest part was maintaining a balance between the loyalty to your career staff and being supportive of the political agenda of any Administration. Career staff expect you to be their voice, their protector, and somebody that makes sure their views are heard and understood. But at the same time, you have to also be the interpreter of the political process and the political decisions, and make sure career staff feel comfortable with the things that are being asked of them.

I actually enjoyed acting in this role, but it was challenging. I recognize that the political agenda at the time was not as partisan as it is right now. In my time at FHWA, you could really say that transportation was largely a bipartisan issue. Both parties were looking to do similar things, to solve the same problems, and so they found ways to come to the middle. The political environment of late has become more challenging.

Everett: You faced a major challenge in August 2007 when the I–35W bridge in Minneapolis, MN, collapsed, killing 13 people and injuring many more. How did that tragedy challenge you as the leader of FHWA?

Wright: There was a lot of panic initially, and I knew it was important to be a calming presence and to be responsive. A lot of people around the country were looking for answers, and FHWA was the only entity that was going to be able to figure out what had happened and what direction to take. There were several parts of FHWA that had pieces of the responsibility—from the Minnesota Division Office, to the Directors of Field Services, to some program offices, even to the Federal Highway Administrator and the U.S. Secretary of Transportation. And I saw my role as pulling all the pieces together.

In the end, I thought FHWA really showed its positive stuff in the face of this crisis. We knew what to do and got a handle on things pretty quickly and effectively. We coordinated what we were doing and our messaging with the Office of the Secretary, the White House, and others. I remember being with (then) U.S. Secretary of Transportation Mary Peters at the White House a couple of days after the incident, and she did a press event at the White House after giving briefings to the Administration leaders.

I thought this was a great example of how FHWA responds to a crisis: remaining calm, making sure people do their jobs, showing competence, and helping the division offices, which are under a lot of pressure from their respective States to immediately deliver things that may be hard to deliver right away. I always wanted to play the role of protecting the divisions and making sure they had the resources needed to work with all the entities involved.

Everett: What is the one accomplishment you are proudest of from your time as executive director of FHWA?

Wright: That is a hard question. This may not be what people expect because it is something that occurred before I was executive director, but I felt proudest around the passage of ISTEA [Intermodal Surface Transportation Efficiency Act] in the early 1990s. At the time, I was working as a special assistant in the FHWA administrator's office. I went there after I was in the [Office of Policy and Governmental Affairs],

(Left) AASHTO's Bud Wright (left) and FHWA's Thomas Everett (right) sat down together before Wright's retirement at the end of 2018 to capture his reflections on his experiences leading both agencies. *Photo: FHWA.*

In his leadership roles, Wright faced a lot of challenges. One of the most notable was FHWA's response to the I–35W bridge collapse in Minneapolis, MN, in August 2007. *Photo: FHWA.*

Under Wright's leadership, FHWA responded to the I–35W bridge collapse by taking a coordinating role, bringing together stakeholders. *Photo: FHWA.*

so I had some background with a lot of the issues that were being grappled with. I had the confidence of FHWA political appointees, and I had the chance to spend a lot of time on Capitol Hill with our very senior people, including the administrator and secretary.

Without question, ISTEA was one of the most significant pieces of surface transportation legislation in the 20th century. It really changed the way we think of surface transportation, and I felt I had the chance to be part of that dialogue in a different way than I did as the executive director.

There is no getting around the fact that, in a lot of ways, it is easier when you are the advisor rather than being the person who makes the final decision. A State chief executive officer (CEO) once said to me that it is a lot different being in the room than being in the chair, and at that time I was in the room. It was great fun. I not only got to advise FHWA leadership, but also I was able to advise members of Congress on a piece of legislation that I felt made a real difference.

And then, 1 year after ISTEA passed, I became FHWA division administrator in Nevada, and I was able to be part of implementing the new law. That was the bill that created the transportation enhancement program, and we did one of the first transportation enhancement projects in the Nation in Las Vegas—an urban, overhead pedestrian crossing. Before then, thousands of people would cross that intersection at grade, and it was a mess, as you can imagine. This new program made it possible for projects to address those kinds of situations. It was really cool.

But, please know there are a lot of things that happened while I was executive director that I can say I was proud of. And I was certainly proud to serve as executive director. The thing I remember most about FHWA, whether I was the executive director or in any other position, is that everyone wants leadership to succeed, especially when they can see that you trust them and empower them.

Everett: In your role as executive director for AASHTO, you have observed FHWA through a different lens. From that perspective, how has FHWA changed since you were our executive director?

Wright: I think it has changed in some ways. During much of my career at FHWA, we were still more in the era of project oversight and just starting to enter the era of stewardship. Our relationships then were not as strong with State departments of transportation as what I see today. For the most part, I think that is because it was not clear in every instance that we were trying to be on the same page with the States. There was a little bit more of a focus on FHWA being there just to make sure everyone was abiding by the rules. Also, laws about more local empowerment were just starting to take hold in the 1980s and 1990s, and this was a real change for a lot of Division Offices. We were struggling with how to strike the right balance of making sure that Federal resources were being used in accordance with the law, but at the same time, not standing over States as a regulator.

FHWA has come a long way in changing from that mode of operating, partly out of necessity because the agency has far fewer employees than it did in those days. This change—from regulator to partner—has been one of [the] most positive developments. I hope this direction continues.

Everett: FHWA is interested in sharpening our focus, making sure we are using our available resources on those things that add the most value to our programs and partners. As you think about the future, where should FHWA be focusing?

Wright: FHWA will always play an important role in helping State DOTs work through the process. A lot of it has to do with interactions with other Federal agencies. This can be within the Department of Transportation or in other places in the Federal Government.

FHWA has to continue to lead in research and innovation. When resources are limited and when budgets are tight, funding for research does not have that same constituency as funding for delivering projects. I think it is important that FHWA take the lead because it is hard for any other organization to do it. FHWA should continue to push research results and deploy innovations through programs like Every Day Counts and the second Strategic Highway Research Program.

What I have seen both while I was at FHWA and at AASHTO is that States can be relatively conservative because they are working with public resources. It is difficult for them to justify using new products or techniques that are not state of the practice. FHWA needs to continue to push innovations. Otherwise, it is just too easy for a State or local agency to fall into a trap of not wanting to take a risk without that push and support from FHWA. Research and innovation deployment go hand in hand.

Everett: Are there one or two things FHWA could do differently, or stop doing altogether?

Wright: When I was between FHWA and AASHTO jobs, I remember somebody from the industry asking me why we even need a Federal Highway Administration and what is it that FHWA is doing that States could not do themselves. It threw me that someone could have that point of view. It is important that FHWA have a broad, comprehensive agenda. And having represented both sides, I'd say one of the keys in working with States is having offices in every State like FHWA Division Offices. I think the other modes lack this advantage, and, maybe in the future, having a one-stop shop

Wright and former U.S. Secretary of Transportation Mary Peters pose for a photo together following an award ceremony.
Photo: FHWA.

for a combined surface transportation program would not be a bad thing. Some of [the] good things that FHWA has been able to do on the highway side could be shared with the other modes, and I think the delivery of transportation services could be improved.

Everett: The topic of FHWA's organizational structure most likely came up at least once while you were executive director. As FHWA works to sharpen its focus, optimize the use of its resources, and organize for the future, what do you view as the most important considerations going forward?

Wright: If I had to say what is most important looking at FHWA's organizational structure going forward, it is making sure you do not lose the focus on State-level relationships. I think State-level presence is key. It is the level at which support and assistance really make a difference. It really works when FHWA takes the partnership approach that it has taken.

FHWA Division Offices should be part of the regular meetings that take place in a State, with FHWA present to help States get things done and not just to say if they are following a rule. This, to me, is the most important thing. Could you reorganize FHWA headquarters and do things differently? You might, but I am not sure that would change anything substantially and I'm not sure that is where I would put my focus. I would make sure that whatever organizational structure FHWA has makes the relationships with States the strongest they can be.

Everett: Let us shift to your transition to AASHTO. When you joined AASHTO in 2012, about 5 years after leaving FHWA, how did your experience at the helm of FHWA help you prepare for the executive director role at AASHTO?

Wright: It helped a lot. First of all, I had many relationships both with FHWA staff and with the CEOs of State DOTs. That helped tremendously. And, having led FHWA helped me with decision-making. Even though I was not facing the exact same issues and decisions, I had the confidence to know the challenges at hand were not so out of the box that I could not manage them. It made me feel more confident early on.

But, what I did learn quickly is that I knew diddly about running an association, particularly the business aspects. Leading an association was a lot different than being the executive director of a Federal agency. I was not prepared to have to address things like changes to the rules with the Affordable Care Act, for example. The Office of Human Resources at FHWA would just take care of that, unlike at AASHTO. Also, while AASHTO is a nonprofit, it also is a business. I have to be able to pay salaries and pay rent. I had not played that role before, and it was a learning curve. But, I did learn at FHWA (as executive director and in the other positions I held) that I can figure things out and learn who to rely on for the best advice.

Everett: What were your priorities at AASHTO?

Wright: At the time I joined AASHTO, we were on the cusp of needing a new surface transportation reauthorization. It was important that we worked with our membership to figure out what States wanted in reauthorization. More important, perhaps, is that we had not redone a strategic plan in 7 years and, as part of that, defining what members wanted the association to be. It was important to me that the membership define AASHTO. We have done that and we continue to emphasize that everything we do is member driven. AASHTO exists only because State DOTs want it to exist, and the members have to drive AASHTO's priorities.

I also thought it was important that AASHTO assist the States in focusing on transportation solutions rather than modal solutions. I started by spending time just listening to where the members wanted to go with this. I think most States do a much better job at this now

Wright helps to cut a cake with other FHWA employees as part of a celebration of the 50th anniversary of the Interstate highway system in 2006. *Photo: FHWA.*

Former Federal Highway Administrator Rick Capka honors Wright with his Senior Executive Service flag during Wright's retirement from Federal service in 2008. *Photo: FHWA.*

compared to what they did 5 years ago. The focus on transportation solutions, as well as the AASHTO reorganization, actually came out of our strategic planning process.

Everett: I have always felt that FHWA and AASHTO have had a productive and healthy relationship. Although positions or objectives may sometimes differ, we've historically been able to work through those differences and advance our programs. From your perspective as former executive director at both FHWA and AASHTO, what has worked well and what needs improvement?

Wright: I agree about the importance and strength of the relationship. One of the things that I had to occasionally remind your FHWA predecessors of—and myself sometimes too—is that AASHTO is not synonymous with State DOTs. It is an association that represents State DOTs, and primarily we function here in Washington, DC. FHWA has sometimes believed that if you had the relationship with AASHTO then you have covered all the States. With FHWA Division Offices in every State, I do not think you can consider discussions in DC with AASHTO synonymous with talking to all the individual State DOTs. The relationship with AASHTO is an important one because it does have a sense of the pulse of the State DOTs. However, AASHTO members expect to have the kind of relationship with FHWA and USDOT where we can make sure their views are heard by senior FHWA officials.

But would I change anything? Well, as I mentioned, the relationships between FHWA Division Offices and State DOTs are so important that I think AASHTO and FHWA leadership in headquarters could work more on making sure relationships between individual division administrators and individual State CEOs are strong. We could be making sure the parties trust each other, even when they do not agree, and that they can have collegial conversations. AASHTO and FHWA could do this in such a way that we are not stepping over boundaries.

Everett: AASHTO has a new executive director, Jim Tymon, and I am new to the executive director role at FHWA. What general advice can you offer me and Jim in our new roles? By the way, Jim and I are off to a great start. We found out that we grew up in the same town and went to the same high school.

Wright: That is really great. I would say to you both to focus on people. Relationships are so important. I am not just talking between you and Jim and the other senior people. I'm talking about relationships across the board. If people see that you are focused on them, empowering them, that you care about them, they are going to want to support you. I think Jim knows that and I would give you the exact same advice. For him, it is his members and his staff. For you, I think it is State CEOs, your own staff, and political leaders as well. As I said at the beginning, your staff members will look to you as their protector and advocate. And you will decide a lot about the careers of individual people. I never took that responsibility lightly, whether at FHWA or at AASHTO. It weighed on me.

The people are the best part of your job. Dealing with people can be the most enjoyable—and can be the most challenging—aspect. You get all the work you need to get done by focusing on the people, and making sure they have what they need to do their jobs within your power and within your limits. And, do it as compassionately as you can.

Everett: For what it is worth, you have left that legacy at FHWA of focusing on people. You were that kind of leader that cared about people. The things you did, your management style, demonstrated this. It meant a lot to us at FHWA. It still does.

Are Your Roads Weather Savvy?

by Paul Pisano

Some transportation agencies are choosing innovative solutions to better manage adverse weather conditions on their roadways—saving lives and enhancing mobility.

Heavy rain, snow, ice, dust, fog, and other adverse weather conditions all cause significant effects on roadway safety, mobility, and economic productivity. Over the last decade, weather contributed to nearly 21 percent of all vehicle crashes. On average, nearly 6,000 people are killed and more than 445,000 are injured in weather-related crashes each year. Further, adverse weather causes about 25 percent of all nonrecurring delays, costing the freight industry roughly $3.4 billion and $9.5 billion overall each year for just 85 urban areas alone.

The Federal Highway Administration's Weather-Savvy Roads initiative directly addresses issues caused by weather impacts on the transportation system by promoting two innovative road weather management solutions: Pathfinder and Integrating Mobile Observations (IMO). Pathfinder provides a step-by-step process for building relationships with partners to share forecasts and road conditions, and then provides consistent messaging to travelers. IMO involves enhanced data collection from agency fleet vehicles to improve awareness of road conditions.

"Pathfinder and IMO are two innovative solutions that enable transportation agencies to better manage the highway system under adverse weather, ultimately saving lives and keeping traffic moving safely and smoothly," says Mark Kehrli, director of transportation operations at FHWA.

FHWA promoted the Weather-Savvy Roads initiative through round four of its Every Day Counts (EDC-4) program (2017–2018). State and local agencies may choose to adopt Pathfinder, IMO, or both to more proactively manage their roadway networks ahead of and during weather events.

(Above) The Federal Highway Administration's Weather-Savvy Roads initiative promotes innovative solutions to managing weather impacts on roads. *Photo: © LeManna/Shutterstock.*

Two Innovative Solutions

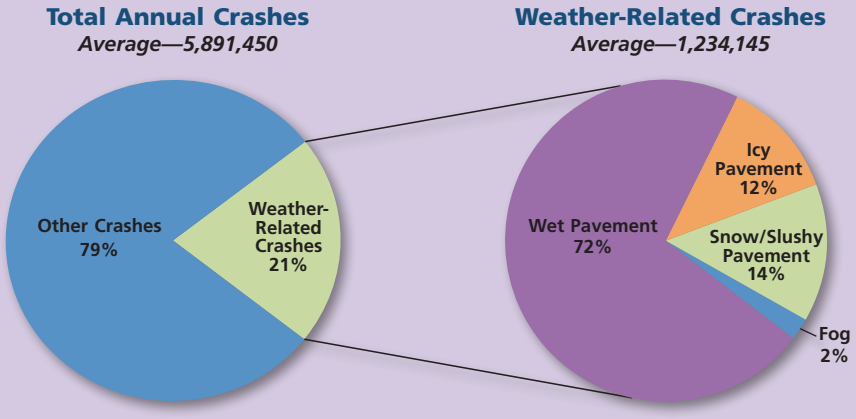
Pathfinder represents a collaborative effort between a State department of transportation, the National Weather Service, and any contracted weather service providers. Specifically, Pathfinder provides an 8-step process to build on existing practices that share forecasts and road conditions among these partners, and then translate that information into consistent messages for the traveling public.

Implementing Pathfinder involves a multistep process of assessing the types of information to share and how to share it before, during, and after high-impact weather events. The goal is to provide the public with consistent and actionable messages on potential impacts on the transportation network.

IMO promotes the collection of weather, road, and vehicle data from agency fleet vehicles to improve situational awareness of road conditions. This initiative builds on the vehicle-based technologies that most States have already implemented in

their vehicle fleets, including automatic vehicle location and real-time communications. IMO enhancements involve ancillary sensors that collect data on weather and road conditions such as air pressure, air and surface temperatures, spreader rate and materials, windshield wiper status and rate, and relative humidity.

Enhanced data from IMO provide maintenance managers with a detailed view of local conditions, as well as the location of assets along the highway network. This information can support maintenance and operations decisionmaking related to road weather forecasts, end-of-shift reporting, material management, traveler information, and performance management.



Twenty-one percent of all crashes annually are weather related. A majority of weather-related crashes are attributed to wet pavement. *Source: FHWA Road Weather Management Program.*

Benefits and Costs

Pathfinder and IMO each improve highway safety, mobility, and productivity. However, the benefits and costs of each vary depending on the nature of implementation.

Pathfinder benefits can include enhanced decisionmaking and better informed travelers, resulting from consistent and targeted traveler information messaging. "We find that the traveling public often looks to multiple sources for weather information," says Jeff Williams, weather program manager at the Utah Department of Transportation (UDOT). "If the traveling public receives the same message about storm impacts no matter the source, we see the traveling public react."

Pathfinder deployments also include the potential for reduced vehicle miles traveled, improved maintenance operations with less motorist impedance, and increased overall safety. The costs associated with Pathfinder are minimal and primarily associated with the amount of time staff at the agency and weather service provider must spend to conduct collaborative activities.

For IMO deployment, a key benefit is material savings from the reduced salt and sand usage. Real-time information about road conditions and fleet vehicle locations assists maintenance staff in making more informed decisions about material applications, which may enable agencies to use fewer materials. In addition, agencies may experience increased efficiencies including improved reporting, reduced time spent relaying information, better situational awareness, and reduced resources needed to respond to emergencies. More comprehensive and accurate real-time information about resource consumption provides agencies with the data needed for decisionmaking. Over time, IMO deployments could also lead to reduced equipment usage and lower legal costs from small tort claims.

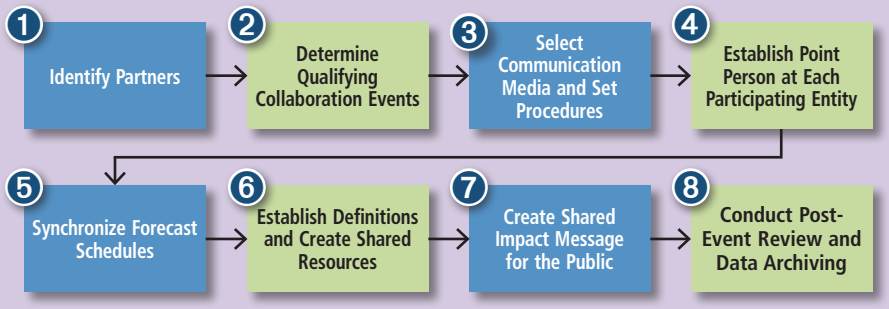
Typical IMO costs may include automatic vehicle location and sensor equipment; communications services; development and implementation of systems to gather, interpret, and present data for action; and systems operations and maintenance. The ways an agency may choose to deploy IMO will affect upfront costs. For example, instrumenting a greater number of vehicles may result in economy-of-scale discounts. Costs vary based on the number and types of sensors mounted on each vehicle. Long-term costs of industrial-grade, commercial off-the-shelf components will be lower than a custom-designed system. Staff training is another cost consideration, particularly when implementing new, unfamiliar systems or for unique, custom-built systems that require specialized skills to design, build, and operate.

Pathfinder in Practice

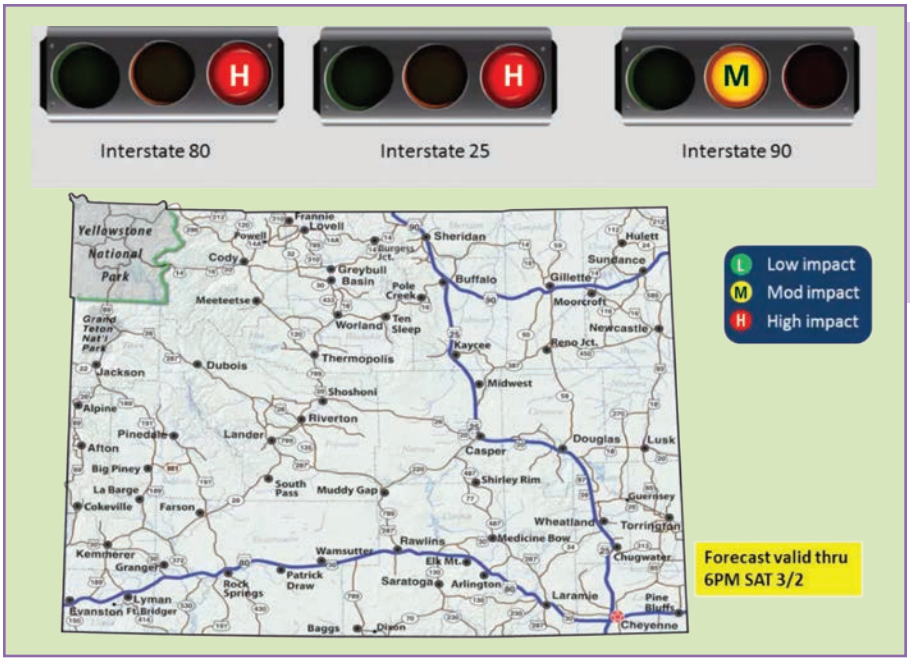
State and local agencies have deployed Pathfinder processes in a variety of ways to best suit the needs of each agency. Currently, 21 States are working to adopt Pathfinder. Pathfinder has proven successful for many State and local agencies, as pilot deployments have demonstrated in Utah and Truckee, CA.

UDOT created the Pathfinder process to improve road weather messaging during the 2002 Winter Olympics. The agency has continued the process because of the successful relationships and outcomes.

UDOT employs Pathfinder processes to ensure that the public uses road weather messages to make



Pathfinder promotes an 8-step process for improved collaboration between DOTs, weather service providers, and other stakeholders. *Source: U.S. Department of Transportation.*



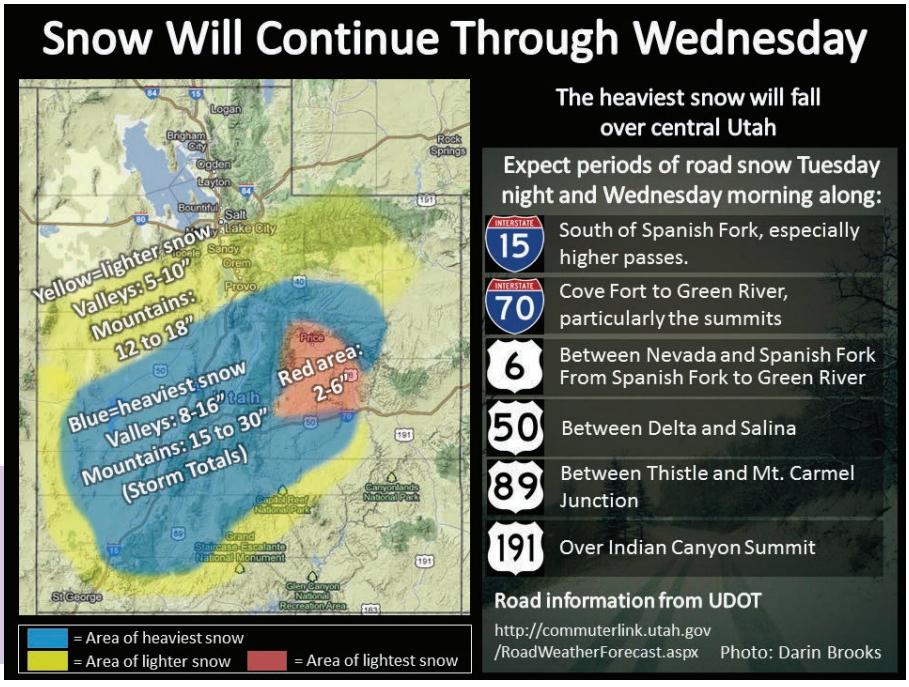
The Wyoming Department of Transportation, with the help of a commercial forecasting service, collaborates with the National Weather Service to create and disseminate Pathfinder videos to help communicate anticipated weather-related travel impacts to the public. *Photo: Wyoming DOT.*

appropriate travel decisions in advance. Improved relationships between UDOT, the National Weather Service, and a private-sector weather provider have helped to sync messages from media and weather outlets on road weather impacts and increase public trust in UDOT traveler information systems. Travelers who take actionable steps based on the information they receive will likely experience safer trips and overall improved mobility.

The benefits of Utah's Pathfinder process include enhanced decision-making and better informed travelers through consistent and targeted traveler information messaging, as well as improved maintenance and increased safety. UDOT and the National Weather Service conducted a survey of 800 travelers following two winter weather events in 2013. Results showed that 97 percent of travelers gathered information about the event with 83 percent of individuals using multiple sources of information. Of the respondents, 66 percent modified their travel plans by: changing their schedule (62 percent), changing the route (26 percent), not traveling (13 percent), or using transit (6 percent). UDOT also reported improved snowplow effectiveness, reduction in costs, and improvement in efficiency because of shared resources among agencies.

At a local level, Truckee, CA, is located on I–80 near the Nevada border with a population that greatly increases on weekends and holidays during the summer and winter seasons for recreational purposes such as skiing, snowboarding, and water-based activities. Extreme vehicle and truck crowding occurs during winter closures on the interstate. Weather events include large amounts of snow and heavy rain with a high risk of flooding. Town officials recognize that severe weather events that may cause dangerous driving conditions require one cohesive message, coordinated with other agencies, to ensure safe mobility, and reduced confusion.

Using Pathfinder principles, the town built direct relationships with the National Weather Service to obtain and discuss severe weather forecasts, warnings, and watches ahead of major weather events. At the same time, Truckee fostered relationships with District 3 of the California Department of Transportation (Caltrans) for insights related to I–80 operations and traffic. These relationships are essential to Truckee's road operations decisions and communications with travelers. In addition, relationships with law enforcement and emergency responders help coordinate operations and public messaging during severe weather events. Working across these agencies with Pathfinder ensures the



This is a screenshot of the National Weather Service weather story for Utah showing a map of snow impacts and listing the specific impacts to major roadways. *Photo: UDOT.*

The Minnesota Department of Transportation installed this onboard mobile data computer in a snowplow truck cab as part of the agency's IMO deployment. *Photo: MnDOT.*

public receives consistent, meaningful messages for making smart decisions.

Truckee noted the following Pathfinder benefits:

- *Enhanced weather knowledge*. A direct relationship and communication with the National Weather Service has improved Truckee's knowledge of expected severe weather significantly, enabling the town to more effectively prepare its response.
- *Expanded public information and outreach*. Providing critical information to the public through Truckee's web portal about road conditions has improved operations, increased safety, and enhanced public trust.
- *Improved efficiency and effectiveness of road operations*. Enhanced weather knowledge and public outreach have improved operations. The town can better allocate resources, mitigate known problem areas, operate more effectively with fewer motorists on the roads, reduce environmental impacts, and enhance safety through generally better road conditions year-round.
- *Increased public relations*. Providing complete information to the public and stakeholders, including trouble spots and real-time road operations, has significantly increased public relations between the town, the traveling public, and other entities.

Expanding Use Of Pathfinder

The FHWA Road Weather Management team has helped to support a number of agencies interested in deploying Pathfinder, often by facilitating an onsite workshop or peer exchange for interested stakeholders to learn more. Several agencies have initiated a Pathfinder pilot as a result of these efforts, including Kansas, Minnesota, and Nebraska.

The Minnesota Department of Transportation (MnDOT) Pathfinder pilot occurred during the 2017–2018 winter season. The agency activated Pathfinder every time the National Weather Service issued a blizzard warning. The pilot also included implementing a National Weather Service chat room with instant messaging service for MnDOT to enable staff to better monitor updates and briefings with MnDOT, the National Weather Service, and the MnDOT weather service provider.

The collaboration facilitated weather updates and consistent messages for the public. The pilot was successful in its first season given the increased collaboration, improved working relationships, and enhancements to the Pathfinder program. The pilot generated a variety of lessons learned for involved stakeholders to expand and improve the process for the subsequent winter season. For example, to ensure all key individuals are included in Pathfinder briefings, MnDOT will create an email distribution list.

IMO Success Stories

Thirty-five State and local agencies have deployed IMO, including 24 States that have committed to adopting IMO as part of EDC-4. For example, Minnesota and West Des Moines, IA, have each deployed IMO technologies and demonstrated success.

MnDOT has been incrementally implementing an IMO program with a goal to improve existing processes and enhance the capabilities of mobile data acquisition systems. MnDOT instrumented 478 heavy duty trucks, 20 light duty trucks, and 5 mowers over 3 phases of IMO deployment. MnDOT collected data from the vehicles and external sensors using customized software and equipment, then transmitted the data to servers via cellular and dedicated short range communications. MnDOT staff used the data for road weather conditions, end-of-shift reports, material management, traveler information, and maintenance decision support.

MnDOT has benefited from its IMO efforts through the experience and involvement with the various technologies. Internal data sharing and reporting helped the agency to achieve savings on material costs and to understand how the savings result from specific maintenance actions. Specifically, plow operators input the amount of chemical applied by route at the end of each shift, which they gather from the automatic vehicle location screen. MnDOT maintenance managers then compare

Sources for Funding Mechanisms

Agencies seeking to implement Pathfinder and deploy IMO solutions may consider several available funding mechanisms. More information is available through the following sources:

- FHWA Center for Accelerating Innovation: www.fhwa.dot.gov/innovation
- State Transportation Innovation Council Incentive Program: www.fhwa.dot.gov/innovation/stic
- Accelerated Innovation Deployment Demonstration Program: www.fhwa.dot.gov/innovation/grants

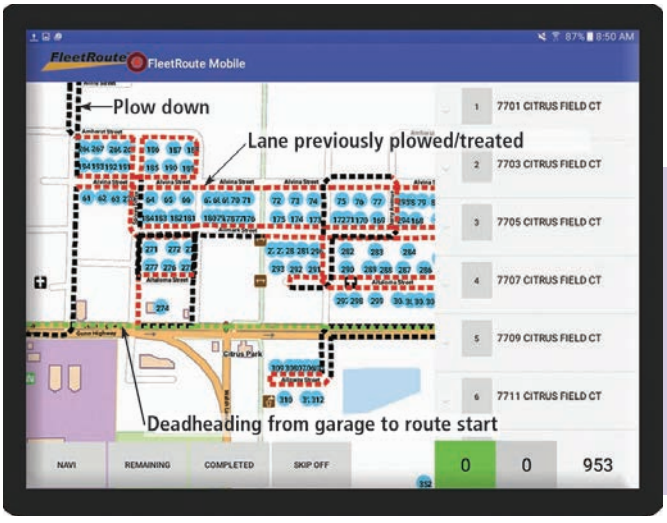
recommended versus applied chemical amounts. Other available data include speed while applying chemicals, average precipitation, end-of-shift reports, material usage by route, and sander status reports. These data support MnDOT's salt sustainability effort to track material usage in a more efficient manner. MnDOT also noted that end-of-shift reports have resulted in a labor cost savings and a grassroots support for IMO technology.

At a local level, West Des Moines is a suburban community of 68,000 residents with 800 lane miles (1,290 kilometers) of pavement. Located at an interstate crossroads, the daytime population increases to more than 150,000 people. The extensive commuter traffic, combined with winter weather conditions in the area, demands effective road weather management strategies.

The West Des Moines Public Services Department leverages available resources to deploy new technologies and equipment to improve its winter maintenance operations. Efforts have included deploying infrared sensors for assessing pavement slickness, automatic vehicle location and mobile sensors on plows and other agency vehicles, software for route optimization, and a maintenance decision support system (MDSS) for material type and application determination.

West Des Moines' savings from reduced salt and material use (while providing the same level of service) far exceeded the costs of the technology. Specifically, the agency has reduced chloride application by 30 percent, saving about $150,000 annually. The city's MDSS uses the available real-time road weather conditions and fleet vehicle locations to provide recommendations on material type, application rates, and timing for maintenance staff to make better decisions.

Route optimization has increased efficiency, reducing the time needed to clear various areas, fuel consumption, and wear and tear on the plow truck fleet. These efficiencies result in about $50,000 savings per year and the ability to do more with less. In addition, with increased data available for review after a winter weather event, agency staff can examine the storm's progression using road weather data such as friction data and photos from a road weather information system, and then compare it to the operational strategy and results. In this way, the city can modify and enhance its strategy for truck placement, material type, and timing of material application to better meet level-of-service goals for future winter weather events.



West Des Moines Public Services has implemented route optimization for plows. This screenshot from the software application shows routing suggestions that more effectively meet level-of-service goals in a timely manner for arterial, collector, and residential networks. The various dotted lines depicted in the image indicate several activities including deadheading—or when plows are not actively plowing in that section of roadway—from the garage to the start of the route, when the plow is down, and a lane that was previously plowed and treated. *Photo: West Des Moines Public Services.*

Toolkit and More Resources

For agencies interested in more information about deploying Pathfinder or IMO in their region, FHWA has created a Weather-Savvy Roads Resource Toolkit. The toolkit houses fact sheets, case studies, early adopter reports, videos, guidance documents, and other implementation resources in a central location at https://go.usa.gov/xnSqy. Specific resources that agencies may find helpful include the Pathfinder implementation guide, *Collaboration Across the Road Weather Enterprise: The Pathfinder Project* (FHWA-HOP-16-086), available at https://ops.fhwa.dot.gov/publications/fhwahop16086/index.htm, and the IMO early adopter final reports, which are available at https://collaboration.fhwa.dot.gov/dot/fhwa/RWMX/SiteAssets/resources-early-imo.aspx.

"It's really important to have the ability to monitor weather events and their potential impact on roads," says Randy Graham, deputy chief of the Science and Technology Infusion Division at National Weather Service's Central Region, "Because weather is one of the only things that has an impact on the entire road system at one time."

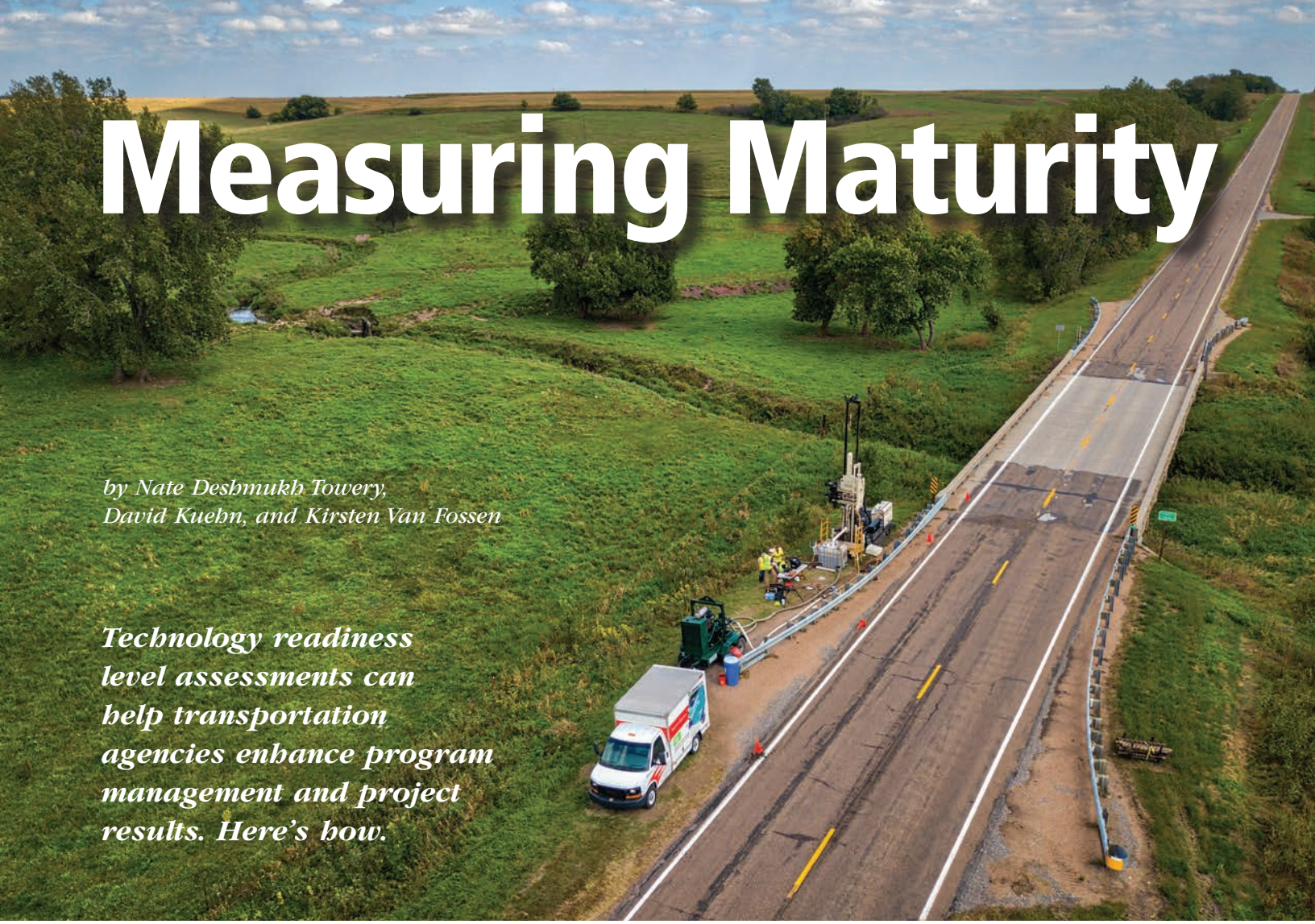
Paul Pisano recently retired as the team leader of the Road Weather and Work Zone Management Team in the FHWA Office of Transportation Operations. He holds B.S. and M.S. degrees in civil engineering from the University of Maryland.

For more information, see https://go.usa.gov/xnSqy or contact Roemer Alfelor of FHWA's Road Weather Management Program at 202-366-9242 or roemer.alfelor@dot.gov.

Measuring Maturity

by Nate Deshmukh Towery, David Kuehn, and Kirsten Van Fossen

Technology readiness level assessments can help transportation agencies enhance program management and project results. Here's how.



New technologies to solve transportation challenges are emerging constantly, and existing technologies can be applied in new ways. For example, early government research during the 1970s looked at ways that radio-frequency identification could be used in the movement of hazardous materials or agricultural products. Later, researchers realized that this technology could be applied to transponders to solve the problem of slowed traffic and congestion at highway toll booths. In the 1980s, private companies ran demonstrations with test vehicles before early adopters made toll transponders available for the first time for public use in 1989. The technology has continued to improve, making way for completely automated toll lanes and highways with no booths at all.

Researchers demonstrate FHWA's in situ scour testing device in Nebraska. A technology readiness level assessment helped the research team determine the next steps for the project. *Photo: FHWA.*

State and local agencies need to be able to assess new technologies for deployment or further development. But, how can agencies make the best, most informed decisions about which will be most beneficial for reaching their goals? Understanding the maturity of a technology is critical to making investment and policy decisions for transportation research. However, assessing maturity can be complex, costly, and time-consuming.

Determining the technology readiness level (TRL) is a way for everyone involved in a project to use a defined scale to assess a technology's maturity. TRL assessments provide guidance to simplify the process, determine the maturity of technologies, and identify next steps in the research process. The Federal Highway Administration has applied TRL assessments to a broad range of research across industries and project types. Using TRLs offers several benefits for transportation researchers and program managers, including improved project communications, project outcomes, and research program management.

The TRL Scale

TRLs are formal metrics that support assessments of the maturity of a particular technology and create a framework for comparing levels of maturity between different technologies. The National Aeronautics and Space Administration (NASA) implemented the initial scale in 1974 to assist in the selection of technologies for further development and mission deployment in the space program. However, the appeal of TRLs as a structured evaluation tool has extended their use to the fields of energy, software, and

manufacturing, among others. The TRL scale is the predominant tool for assessing technology maturity across disciplines and industries.

Over time, the scale has been modified and refined. The current TRL assessment process ranks a technology using a nine-point scale grouped into four categories of progression from concept to implementation: basic research, applied research, development, and implementation.

The TRL scale assesses technology in terms of certain characteristics, such as whether system performance metrics have been established, end-user requirements documented, or a prototype tested in a realistic and relevant environment outside the laboratory. Researchers measure these characteristics through completed tests appropriate to the specific technology.

The scale considers two aspects of conducting the tests. The first is how complete the technology was when it was tested: Was it a paper-and-pen concept, a system of equations, a component, a subsystem, or the complete system? The second addresses the representativeness of the test environment: Was it a computer simulation, a controlled laboratory experiment, a demonstration at a proving ground, or a real-world test? In addition, this component of the TRL assessment considers how similar the tester was to the ultimate technology user: Was the tester the developer of the technology, another expert in the field, or a user with no more specific knowledge than the typical user?

Each level of the scale offers requirements framed as questions to help determine where a particular technology should fall. By focusing on completed tests and a typical progression of testing toward technology adoption, the TRL scale facilitates a structured approach for indicating immediate next steps for a research project. Considering and debating the questions that comprise the TRL scale guides all parties involved in TRL assessments to a shared understanding of the technical state of the project. The discussion involved in assigning a readiness level to a project can uncover technical gaps and questions that point toward next steps in the technology's development.

Category	Technology Readiness Level	Description	Requirements
Basic Research	1	Basic principles and research	• Do basic scientific principles support the concept? • Has the technology development methodology or approach been developed?
	2	Application formulated	• Are potential system applications identified? • Are system components and the user interface at least partly described? • Do preliminary analyses or experiments confirm that the application might meet the user need?
	3	Proof of concept	• Are system performance metrics established? • Is system feasibility fully established? • Do experiments or modeling and simulation validate performance predictions of system capability? • Does the technology address a need or introduce an innovation in the field of transportation?
Applied Research	4	Components validated in laboratory environment	• Are end-user requirements documented? • Does a plausible draft integration plan exist, and is component compatibility demonstrated? • Were individual components successfully tested in a laboratory environment (a fully controlled test environment where a limited number of critical functions are tested)?
	5	Integrated components demonstrated in laboratory environment	• Are external and internal system interfaces documented? • Are target and minimum operational requirements developed? • Is component integration demonstrated in a laboratory environment (fully controlled setting)?
Development	6	Prototype demonstrated in relevant environment	• Is the operational environment (that is, user community, physical environment, and input data characteristics, as appropriate) fully known? • Was the prototype tested in a realistic and relevant environment outside the laboratory? • Does the prototype satisfy all operational requirements when confronted with realistic problems?
	7	Prototype demonstrated in operational environment	• Are available components representative of production components? • Is the fully integrated prototype demonstrated in an operational environment (real-world conditions, including the user community)? • Are all interfaces tested individually under stressed and anomalous conditions?
	8	Technology proven in operational environment	• Are all system components form-, fit-, and function-compatible with each other and with the operational environment? • Is the technology proven in an operational environment (meet target performance measures)? • Was a rigorous test and evaluation process completed successfully? • Does the technology meet its stated purpose and functionality as designed?
Implementation	9	Technology refined and adopted	• Is the technology deployed in its intended operational environment? • Is information about the technology disseminated to the user community? • Is the technology adopted by the user community?

The EAR Program and TRLs

FHWA's Exploratory Advanced Research (EAR) Program focuses on high-risk, high-reward research that fills the gap between basic and applied research. It also supports the development of transformative research tools with potential highway benefits.

Capturing the core of a research project succinctly while offering tangible next steps is a difficult undertaking. The EAR Program needed a system to describe the maturity of highway research projects. In 2014, EAR Program researchers began using TRL assessments as a tool to improve project outcomes, project communications, and program management.

By codifying completed tests and proposing a sequence of future research and development activities, a TRL assessment can support strong project outcomes. The assessment results usefully indicate what sort of development may be necessary to mature the technology to the next readiness level, although the level of effort required will vary across TRLs and projects.

TRLs improve project communications by providing a common language across industries and disciplines. The structured process used to assign a TRL to a technology helps to create a common understanding, rather than relying on terms such as "market ready" or "deployment ready," which may mean different things to different audiences. This common language for discussing technology readiness is particularly helpful when handing off technology between different groups involved in development, or for communicating the technological readiness of a project to decision-makers who are determining where and how to invest research funding.

Research program management also can benefit from introducing TRLs. Some agencies choose to use TRLs as a decision gate, requiring that a particular TRL must be achieved to advance the technology to a next stage of funding or implementation. Alternatively, project teams can use TRLs as an informal check-in to bring experts and stakeholders together to discuss appropriate next steps.

The cross-disciplinary nature of the assessment is useful as a portfolio tool for larger research programs. Research program managers can use TRLs to understand if investment is occurring at the intended stages of development, and to assess the general level of progress.

Preparing for and Conducting the Assessment

When preparing for a TRL assessment, those involved should consider several key elements. Project leaders must first agree that the TRL assessment is an appropriate tool for their purposes. Preparation then consists of four major components: selecting panelists, establishing clear goals, formalizing timing and location, and creating materials.

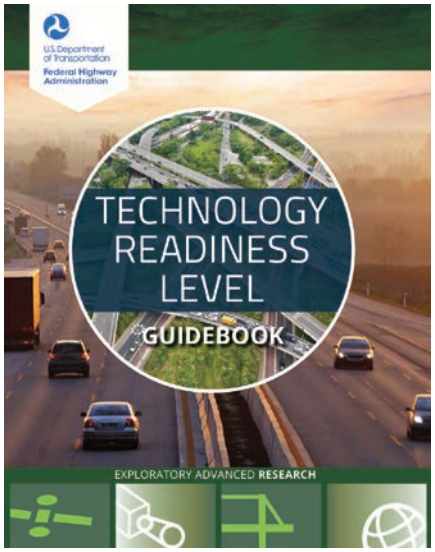
Convening a well-rounded panel of experts to assess the maturity of a technology is essential to the success of a TRL assessment. For most research projects, a panel of four to six stakeholders, researchers, and subject matter experts provides an effective balance. Panelists should at a minimum be knowledgeable about the technology, the potential users of the technology, or the application environment.

Goal setting includes defining why the assessment is being conducted and exactly what is being evaluated. For example, TRL assessment organizers may decide to conduct assessments separately for different components of a project.

After the panel is selected and the goals are determined, the team can set the timing and location of the assessment and prepare and distribute the materials. A thorough materials packet should include all relevant background information, studies, and test results. These should be provided to the panel with plenty of time for review prior to the assessment meeting.

The TRL assessment itself is straightforward. The typical framework includes a brief presentation of the technology by the project's principal investigator, a period of deliberation by the panel, and a discussion with the principal investigator about the results. The last step is an important opportunity for the principal investigator to learn the panel's thoughts on the technology's current maturity and how that maturity can improve.

To help with the preparation and assessment process, FHWA published



FHWA

the *Technology Readiness Level Guidebook* (FHWA-HRT-17-047) in September 2017. The guidebook provides the necessary information for conducting an assessment, offers background on the TRL scale, walks through every aspect of preparing for and conducting a TRL assessment, and provides helpful tools and tips throughout.

Using Assessment Results

To maximize the value of its research and efficiently communicate results, the EAR Program uses TRL assessments along with other tools to help identify research products for further support and audiences that would be interested in the results. TRL assessments also provide a useful foundation for other research planning and evaluation tools, such as logic models and mind maps.

TRL assessments can help project teams identify stakeholders who would be interested in research results at a given stage of maturity. For example, practitioners likely will be more interested in technologies that can be piloted in real-world environments than in basic research without a clearly defined application.

Still, the TRL scale has limits. It describes technology maturity, which is only one factor for continued investment in research and development. Others to consider include the benefits of a technology over existing technologies, development costs, and risks from continued investment. Accordingly, it is important to complement a TRL assessment with other methods of assessing the potential of new

technologies, such as market and barrier analyses, determination of level of effort, and logic models.

Documenting results through reports, peer reviewed papers, and professional presentations is important. In addition, FHWA uses workshops, demonstrations, training, and other communications activities to transfer results from one audience to another. In-person contact and demonstrations give stakeholders an opportunity to see and touch the actual work, ask questions, and interact with the research team, which encourages continued commitment to the work and improved knowledge transfer.

TRL assessments are a valuable tool for a wide range of highway-related technologies and research. Following are four examples of projects that completed TRL assessments and the insights generated through the process.

Web-based Wildlife Observation

The Wildlife Observer Network Web-based system, developed by the Road Ecology Center at the University of California, Davis (UC Davis) developed technology to detect wildlife and capture and transmit images without the need for manual operation of the camera. Remote operation minimizes the required time and personnel resources. Potential users include wildlife camera operators working with State and local transportation agencies.

The technology is a system of components that includes hardware (such as cameras), a Web-based system (online project management platform, database), and people (camera operators). Motion-activated and cell- or Wi-Fi-enabled cameras detect, capture, and automatically upload images of animal sightings to the Wildlife Observer Network's database. The system automatically tags the images with location and time information. Camera operators then analyze the images to identify the animal and discard false positives.

The project team completed a TRL assessment of the wireless technology in August 2016. A meeting at the National Highway Institute convened both in-person and remote attendees including principal investigator Dr. Fraser Shilling of UC Davis, staff from the U.S. Department of Transportation, and representatives from four State departments of transportation. The State DOT representatives served as the TRL assessment panel and provided the perspectives of both technology experts and potential early adopters.

The panel determined the technology to be at level 6, the earliest stage of the development category in the TRL scale. As next steps to mature the project, the panel suggested that the team clearly define performance metrics (such as adoption rates, time savings, and website usability), seek user feedback through a virtual focus group, and integrate the feedback from the focus group into future versions of the system. The TRL assessment also provided the developers with useful feedback regarding the need to explore image transmission methods that lead to higher quality images, enabling improved animal identification.

"The TRL assessment was useful because it was a structured critique of the system [and] approach we have developed," says Shilling. "This allowed both a detailed self-assessment of specific aspects of the technology and an idea from practitioners of where we are in development and how far we have left to go."

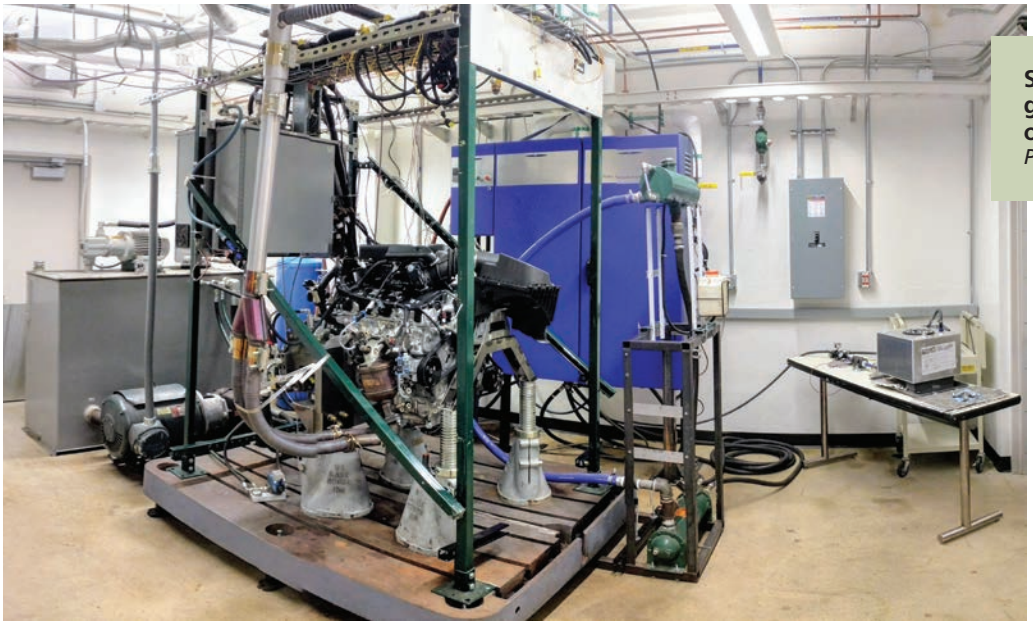
A motion-activated camera in UC Davis' Wildlife Observer Network captured this image of a gray fox, wirelessly transmitted it to a database, and tagged it with the time and location. *Photo: Road Ecology Center, UC Davis.*

Minnesota's HIL Test Bed

The University of Minnesota conducted research with a hardware-in-the-loop (HIL) test bed. HIL technology enables a system to have physical hardware components that interact with simulated components in a simulated environment. The goal is to create an environment to safely test scenarios that would be too dangerous or costly to pilot in the real world.

The University of Minnesota's HIL test bed uses a laboratory powertrain research platform—a real engine, an engine-loading device (hydrostatic dynamometer), and a virtual powertrain model to represent a vehicle—connected remotely to a traffic simulator. The HIL test bed captures actual fuel and emissions measurements, which researchers cannot calculate precisely using fuel and emission maps in simulations.

In May 2017, a TRL assessment for the HIL test bed brought the developers together with representatives from the U.S. Department of Energy's Advanced Research Project Agency – Energy and National Renewable Energy Laboratory, the Minnesota Department of Transportation, and other agencies. After considering the completeness of the technology and the representativeness of the test environment, the panel debated whether to assign the



Shown here is a gasoline engine, part of the University of Minnesota's HIL test bed. *Photo: University of Minnesota.*

Researchers demonstrate the in situ scour testing device in Michigan. *Photo: FHWA.*

HIL test bed a TRL 5 or TRL 6. While the prototype appeared to satisfy all operational requirements, panel members were uncertain if factors such as grade, weight, and classification of the simulated vehicles were truly representative of real-world use.

The debate over the level proved helpful to the researchers in identifying next steps and advancing development. "We were quite encouraged by the high TRL assessment of the HIL system," says Zongxuan Sun, director of the Center for Compact and Efficient Fluid Power at the University of Minnesota. "One area we felt will further enhance the HIL system is to compare [it] directly with actual vehicle tests. With the support from FHWA, we were able to install a new engine in the HIL system that is the same as the engine used in the fleet vehicles at FHWA."

In Situ Scour Testing Device

Traditionally, bridge engineers and researchers have found it difficult to accurately estimate the erosion of fine-grained, cohesive soils around bridge foundations. This erosion, called scour, impacts the structural integrity of a bridge. Established methods use empirical models that assume uniformly graded, noncohesive sands and represent worst-case conditions. However, bridge engineers and researchers consider this approach overly conservative, and it may lead to design and maintenance practices that are potentially unnecessary and resource intensive.

To address these concerns, a team of researchers at FHWA has developed an in situ scour testing device, which works in place (in situ) in conjunction with a standard geotechnical drill rig to measure the erosion resistance of fine-grained cohesive soils in terms of erosion rate and critical soil resistance. Instead of making a typical geotechnical soil investigation, the erosion head of the in situ device is lowered into the bore hole to conduct the erosion test.

The TRL assessment panel for the device, held in November 2017, included FHWA staff and represented potential users. As the panelists learned about how the testing device would be used in practice, they raised concerns about how the device's output compares to the output of existing laboratory-based testing methods. Panelists suggested developers clarify what the output means in comparison to the output from existing tests that scour analysts are trained in interpreting.

While the TRL assessment's primary value is enabling the technology's developers to accelerate their progress, the in situ device's assessment also provided a positive experience for the panel members. Panelists learned about this cutting-edge technology, but also about the TRL assessment process itself. They noted that the experience gave them the confidence to carry out TRL assessments on their own research and other projects in their labs, as well as to promote the use of TRL assessments as a valuable exercise within their organizations.

"The standard format of the TRL [scale] offers a commonsense understanding of the requirements for the progression of technology maturity," says panel member Mike Adams from FHWA's Office of Infrastructure Research and Development. "The TRL assessment establishes the level of maturity, and provides unbiased feedback to the researchers. It is a helpful process to streamline the advancement of technology."

SeeBridge: Semantic Enrichment Engine

The SeeBridge project is one of 9 research projects in the Infravation Program, funded by FHWA in partnership with 10 other countries and the European Commission. The Infravation Program is a cooperative research initiative between FHWA and other national road administrations that enables U.S. entities such as academic institutions, State DOTs, and businesses to participate in the research along with entities from other countries. The SeeBridge project sought to develop a powerful and comprehensive approach to revolutionize surveying and inspection of bridges.

With SeeBridge, researchers collect structural information on bridges using terrestrial laser scanning, or laser scanners mounted on vehicles with high-resolution cameras and video recorders. The technology produces high-density, graphic representations of bridges, called point clouds. Analysts then develop 3D models of the bridges from the point clouds using advanced algorithms. To test the technology, the project team scanned bridges in Georgia, working with the Georgia Department of Transportation, as well as bridges in England, Germany, and Israel.

The TRL assessment of SeeBridge, held in October 2017, recommended that researchers obtain more feedback on integrating the system with agencies' bridge inspection records and management systems. Specifically, the assessment team recommended extensions to current asset management systems to include historic records in the SeeBridge system at the structural element level. The panel also recommended obtaining more data to test the ability to recognize exceptions to common structural elements and further development of the 3D reconstruction steps.

This image of a bridge is created via photogrammetry to permit 3D analysis of the structure for virtual bridge inspection. *Photo: Ruodan Lu, Ioannis Brilakis, Campbell Middleton.*

Since the TRL assessment, the research team has continued to obtain feedback from asset owners and examine how this new technology can integrate with current records and systems. Researchers are planning to pilot the technology on more structures. With increased experience and more data, the team will be able to make the system more robust and advance the technology's maturity.

Expanding the Use of TRLs

With research and development taking place across many different organizations and programs—from Federal agencies to State DOTs to industry—the use of TRLs can smooth the transition and communication of results from one program to another. However, more people need to become familiar with the process to understand its benefits and adopt TRL assessments as a tool. To this end, FHWA worked with the Volpe Center to develop a webinar providing an introduction to TRLs (slides available at www.trb.org/Calendar/Blurbs/173937.aspx) and to produce the guidebook on conducting TRL assessments (available at www.fhwa.dot.gov/publications/research/ear/17047/index.cfm.)

New technology development in the highway transportation system—from mobile sensor data to increased vehicle automation—is increasing the interdependence of research and programmatic areas from infrastructure to safety to traffic operations. Hari Kalla, Associate Administrator with FHWA's Office of Research, Development, and Technology says, "Early consideration of the deployment environment and common understanding of technical maturity will grow in importance as new technologies come into the highway system."

Nate Deshmukh Towery is a technology policy analyst at the Volpe Center. He has a B.A. in history and science from Harvard University and a Ph.D. from the Massachusetts Institute of Technology.

David Kuehn is the program manager for the FHWA EAR Program and has a master's of public administration from the University of Southern California.

Kirsten Van Fossen is an engineer at the Volpe Center, researching innovations with potential sustainability benefits. She has a B.S. in environmental engineering from Harvard University and a Ph.D. from the University of Cambridge.

For more information, see FHWA's Exploratory Advanced Research Program website at https://highways.dot.gov/research/exploratory-advanced-research or contact David Kuehn at 202-493-3414 or david.kuehn@dot.gov.

Making Connections

by Matthew McAllister and Deborah Curtis

The lessons from Denver's collaboration with FHWA's Turner-Fairbank Highway Research Center can help other communities develop a connected vehicle program.

Reading technology magazines may give the impression that all cars will be talking to each other within months. Connected vehicle (CV) technology can enable vehicles to wirelessly communicate with one another, as well as with intelligent infrastructure. But there is a lot for State and local transportation agencies to learn about this technology and its development, applications, installation, and management. The U.S. Department of Transportation and the Federal Highway Administration have resources to help States and municipalities harness this technology, from ongoing projects with the winners of the Smart Cities Challenge to grants and technology demonstrations to help agencies develop and implement CV systems.

One city to take advantage of these resources is Denver, CO. Through a connected system, Denver's Department of Public Works aims to reduce congestion and improve safety. Connected systems can provide more efficient traffic signal priority, or send an alert directly to a vehicle at risk of crashing into a pedestrian who is difficult to see. Vehicles with this technology can more safely pass other cars on the highway, receive alerts about other vehicles in a blind spot, and

Technicians with Denver's Department of Public Works install a roadside unit at an intersection as part of the city's pilot deployment of connected vehicle technology. *Photo: Matthew McAllister, city of Denver.*

report icy conditions to the city so snow plows can be sent out.

In 2015, Mayor Michael B. Hancock selected a team of transportation and technology experts to lead Denver's submission to the USDOT Smart Cities Challenge. While Denver did not win the competition, the city was a finalist, and the congestion and safety components of the plan using CV technology became the foundation for a different, successful Federal proposal. "It is a compelling technology for city engineers looking to improve congestion and safety outcomes," says Michael Finochio, an engineering manager at the Denver Department of Public Works. "We wanted to continue to develop it."

Denver applied for and received an Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) grant in 2016. The funding went toward three projects that are part of the city's broader Smart City mission to use technology and data to improve the health, mobility, and safety of all those who live, work, and play in Denver.

Navigating a Tricky Technology

CV technologies and systems are complex and can present a wide array of challenges. For example, Denver's team installed a roadside unit with a wireless radio device but ran into power management issues on the circuit board and had trouble with the communication link to other connected equipment at the intersection. Unknown capabilities and shifting requirements also challenge agencies exploring new technologies.

"As with all technology projects, though," says Jim Lindauer of Denver Technology Services, "the best thing to do is to dig in, start small, and learn as much as possible."

Denver did this by embracing a "living lab" methodology to test innovative ideas and technologies to understand capabilities and limitations before large-scale deployments. The city identified a set of intersections to enable small, rapid tests of new technology, but still ran into difficulties they sometimes struggled to address.

"We were happy to discover that FHWA and the USDOT Intelligent Transportation Systems (ITS) Joint Program Office (JPO) had experts available to help our team adopt agile development practices," says Finochio.

Agile is a commonly used project management framework in the tech sector where requirements and capabilities are unknown or change frequently—an apt description for Denver's testing environment. In April 2018, experts from FHWA offered a technical assistance session in Denver at which the project team learned about approaches to procurement for and management of agile and open-source projects. The day included a discussion of resources available to help early adopters like Denver.

The most immediately beneficial resource was an equipment loan and technical help desk service run through FHWA's Turner-Fairbank Highway Research Center (TFHRC). Established as part of USDOT's CV Pilot Deployment Program, this service offers agencies short-term loans of the latest equipment and addresses their frequently asked questions based on lessons learned from other projects.

Denver was early enough in the process that the team did not know exactly what requirements to include in a solicitation for devices. "We started testing to see how these devices would work with our existing technologies in a living lab environment," says Emily Silverman, the Smart City program manager in Denver. "The equipment loan program was the perfect solution. Within a few days, devices were on their way, free of charge, to Denver."

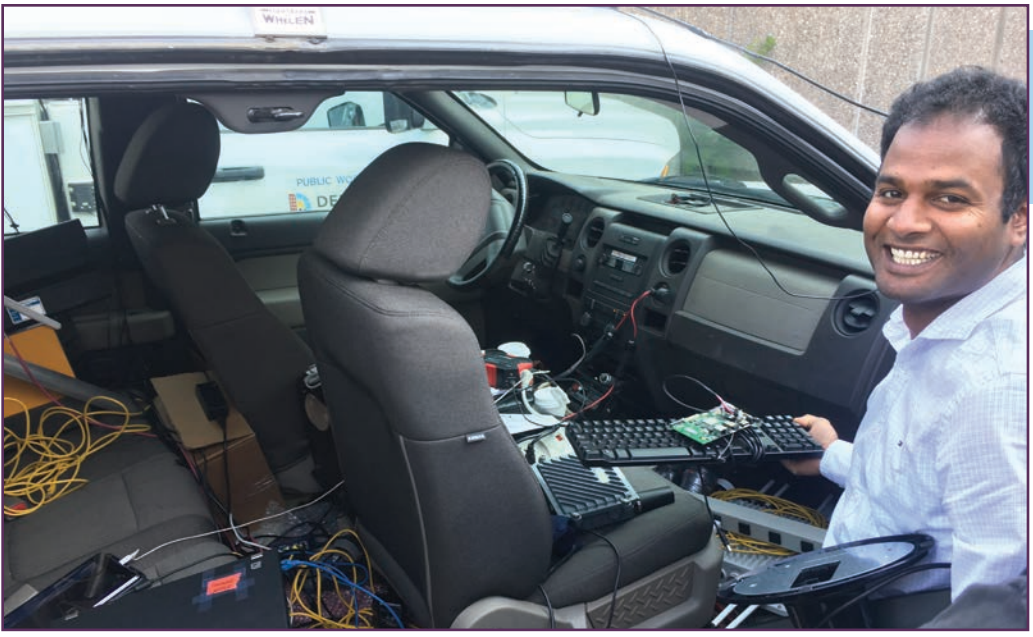
Borrowing equipment from TFHRC includes the benefit of direct communication with technical support staff. TFHRC's Saxton Transportation Operations Laboratory works with a contractor to offer Connected and Automated Vehicle Support Services, which includes an online interface at www.pcb.its.dot.gov/CAVSupportServices.aspx. Denver's technical team collaborated with the support staff to get all of the loaner equipment working with the city's traffic signal controllers, including older generation controllers Denver's team had assumed would not be supported.

"This achievement was a big deal for Denver," says Dave Edinger, Denver's chief information officer. "Our Smart City team operates from a set of core values, including supporting multivendor interoperability and avoiding lock-in."

An Open-Source Solution

Denver's team wanted to avoid overreliance on any given technology or vendor and to deploy solutions that maximize interoperability, that are based on standards, and that maintain city and county ownership of the data. Fortunately, TFHRC had a

Denver's Smart City team at their kickoff meeting for the advanced transportation and congestion management technologies deployment program. *Photo: Matthew McAllister, city of Denver.*



Denver is testing technology that enables two-way communication among vehicles, infrastructure, and traffic signals. *Photo: Matthew McAllister, city of Denver.*

solution: a vehicle-to-everything (V2X) option called V2X Hub, an open-source tool available at www.pcb.its.dot.gov/CAVSupportServices.aspx.

At first glance, V2X Hub may appear to be simple translation software for CV standards to communicate with traffic signal controller protocols. However, that is just the foundation for its capabilities. It provides a platform for public and private partners to work together on applications that improve congestion and safety outcomes. "V2X Hub is a Rosetta stone for the connected vehicle system," says Silverman.

In Denver, the V2X Hub software enabled the city to achieve wide-ranging interoperability between traffic signal controllers and roadside units. The team deployed the code on a single-board Linux processor and placed it on the same network switch as the traffic signal controller and roadside unit.

V2X Hub also aligns with another one of Denver's core Smart City values: to be "open by default." To the maximum extent practical, the city chooses open source solutions over closed proprietary ones, and open data over siloed and closed data. As an open-source tool, V2X Hub enables cities, States, and private companies to build additional plug-ins for CV apps and other functionality. By separating the application layer from the hardware layer—creating tools that can work with a wide variety of devices and equipment—V2X Hub offers Denver the capability to work with multiple vendors to meet the city's needs, incorporate data from other devices at intersections, and build software with collaborators across the country.

This level of collaboration and integration saves money, avoids duplicative efforts, and makes it easier for subsequent cities to get started. "Historically, technologies to improve transportation have been proprietary, making the development and adoption of new technologies more difficult and expensive," says Chris Stanley, senior director of Surface Transportation Research at Leidos and program manager for the Saxton Lab. "By creating standards and an open architecture for interoperability, USDOT laid a foundation that's accelerating the adoption and open-source development of solutions by hundreds of organizations throughout the country. The sharing of information and code has enabled contributors to develop new solutions much more quickly, efficiently, and economically."

Expanding Efforts

Denver's Smart City program is providing actionable data to frontline employees, combining institutional knowledge with technology advances to connect residents to city services. The city's team is excited to build solutions with other communities across the country, continue to collaborate with FHWA, and accelerate the adoption of CV solutions to make the city's transportation system safer and more efficient.

To expand communication and collaboration even further, TFHRC's Saxton Lab launched the V2X Hub User Group. For more information, go to www.pcb.its.dot.gov/CAVSupportServices.aspx.

Tricia Sergeson, a transportation specialist with FHWA's Colorado Division, worked with Denver's Smart City team. She says, "Working with Denver on the connected vehicle deployment has been an excellent example of how USDOT has been able to collaborate and leverage the great research and expertise of the TFHRC, the ITS JPO, FHWA's field division offices, and the Resource Center to help deploy new technologies and innovation."

Look for more features on CV in upcoming issues of PUBLIC ROADS.

Matthew McAllister is the Smart City project manager for the city of Denver, overseeing the connected vehicle Federal grant program. He previously served as the special assistant and policy advisor to the U.S. Chief Technology Officer in the White House Office of Science and Technology Policy. He is a graduate of the University of Colorado Boulder.

Deborah Curtis has been a research engineer in FHWA's Office of Operations Research and Development for 28 years. She leads the Connected and Automated Vehicle Support Services program within the USDOT as well as other infrastructure-based connected and automated vehicle research. She is a civil engineer and graduate of West Virginia University.

For more information, see www.pcb.its.dot.gov/CAVSupportServices.aspx or contact Aaron Greenwood at CAVSupportServices@dot.gov.

Along the Road

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 Case Study Features Dockless Bike Share

The Federal Highway Administration recently published a case study in its livability series highlighting the dockless bike share program in Seattle, WA. The case study examines how Seattle adopted dockless bike share and the manner in which the city successfully leveraged innovation in the private sector to improve mobility in the city.

Seattle Department of Transportation

An FHWA case study examines Seattle's successful dockless bike share program.

Seattle is the largest city in the State of Washington, with a population of nearly 725,000 people—of which approximately 4 percent commute by bicycle. In July 2017, the Seattle Department of Transportation (SDOT) formally adopted citywide dockless bike share.

Traditional bike share systems operate with permanent docks located throughout the system's operating area, where all trips must start and finish. Dockless bike share systems enable users to unlock bicycles with a smartphone app and drop them off wherever they wish, such as in a park or beside a sidewalk, regardless of whether there is a bike rack.

SDOT was the first agency to begin a pilot program at scale. Over the initial 6-month period from July to December 2017, riders took approximately 469,000 rides on dockless bicycles throughout Seattle, nearly 10 times the number of rides on the docked system during the same period in 2016. Moving forward, Seattle is expanding dockless bike share through a new permit approved in August 2018 that will put up to 20,000 bicycles on the streets, from up to four private operators, two of which are currently active.

The case study may serve as a beneficial resource for cities and towns that are exploring how to integrate dockless bike share into their transportation networks.

For more information, visit www.fhwa.dot.gov/livability/case_studies/seattle_bikeshare/fhwahep19008.pdf and www.seattle.gov/transportation/projects-and-programs/programs/bike-program/bike-share.

ITD Expands Outreach with New Podcast

The Idaho Transportation Department's (ITD) Grant Anticipation and Revenue Vehicle (GARVEE) Transportation Program and Office of Communication recently collaborated to launch an ITD podcast. The goal is to use this new communication tool to expand outreach to the driving public prior to major commute impacts on Interstate 84 (I-84). The program intends to reach a different audience than television, radio, or other media.

The focus of the first episodes of the podcast is on widening I-84 in Canyon County. Future podcasts will address significant milestones and upcoming traffic switches as the work in the Nampa to Caldwell corridor kicks into high gear later in summer 2019 and for the next few construction seasons.

The I-84 corridor team brainstormed the podcast idea in 2018 and began to work on the first few podcasts later that year. Vince Trimboli, ITD's communication manager, hosts the podcast and brings on various guest experts to discuss specific topics.

"The podcast is an outreach tool that the department hadn't yet put into practice, and we thought that with the many commuters on the I-84 corridor, perhaps we could give people another way to keep in touch with what we're planning and doing in the corridor," says GARVEE Manager Amy Schroeder, Trimboli's first guest on the podcast.

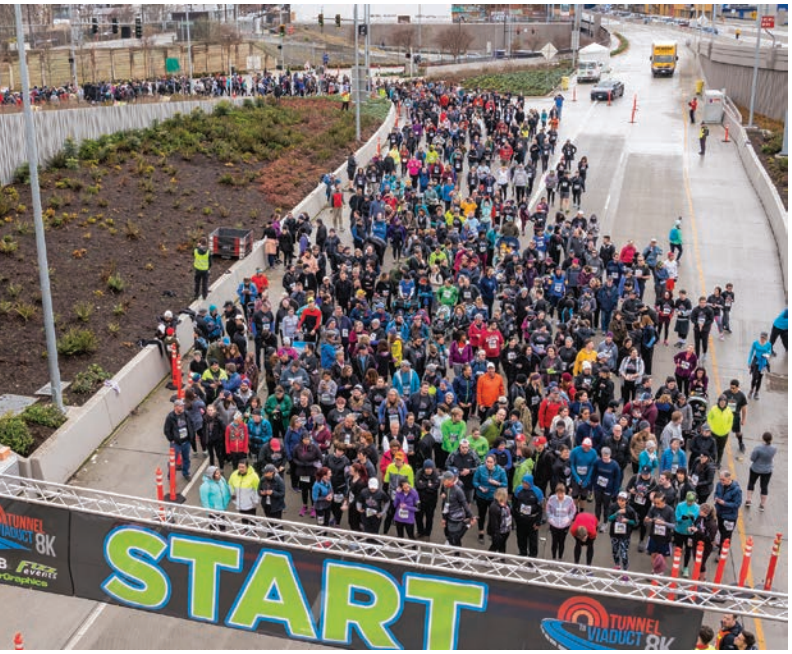
Idaho Transportation Department

The Idaho Transportation Department recently launched its "Drive Idaho" podcast.

ITD chose the podcast name "Drive Idaho" because it represents what the department does every day, and because it can be used statewide. The podcast is available on iTunes at https://itunes.apple.com/us/podcast/drive-idaho/id1450572101?mt=2.

Seattle SR 99 Tunnel Opens to Traffic

In February 2019, Seattle, WA, celebrated the opening of the SR 99 tunnel, which replaces the aging Alaskan Way Viaduct.



Washington State Department of Transportation

Participants line up for an 8K fun run/walk as part of the celebration of the opening of the SR 99 tunnel in Seattle.

Crews began the tunnel opening sequence at approximately 10:30 p.m. on Sunday, February 3. The first vehicle rolled through the tunnel's northbound lanes just after 11 p.m. and by 12:15 a.m. Monday, all ramps to and from the tunnel were open to drivers, with the exception of the new northbound offramp to Dearborn Street, which opened a couple of weeks later. The Washington State Department of Transportation, Seattle Department of Transportation, Seattle Police, and Washington State Patrol coordinated closely to ensure the tunnel was opened safely.

The tunnel is currently toll free, but tolling could begin as soon as summer 2019. Toll rates will range from $1 to $2.25 with a Good To Go! pass, depending on time of day. Users can learn more about how tolling will work at www.wsdot.wa.gov/tolling/sr-99-tunnel-tolling.

GDOT Opens Northwest Corridor Express Lanes

In September 2018, the Georgia Department of Transportation (GDOT) celebrated the opening of the State's largest infrastructure project, the Northwest Corridor Express Lanes. Construction of the project began in October 2014, and the lanes opened to traffic in September 2018.

The $834 million infrastructure project adds 29.7 miles (47.8 kilometers) of reversible express lanes along I–75 from Akers Mill Road to Hickory Grove Road, and along I–575 from I–75 to Sixes Road. The barrier-separated express lanes operate southbound in the morning and reverse to northbound in the evening.

GDOT is responsible for the operation and maintenance of the roadway. Operation of the pricing aspects of the lanes, including all customer service functions related to Georgia's Peach Pass system, is managed by the State Road and Tollway Authority. The lanes feature dynamic pricing with rates rising as demand increases during peak travel times and falling at offpeak times.

The express lanes are open to drivers with a registered Peach Pass in vehicles with two axles and six wheels or fewer. Registered transit, vanpool, and emergency vehicles are exempt from paying a fee.

For more information, visit www.dot.ga.gov/DS/GEL/NWC.

GDOT

Georgia Department of Transportation

Crews work on Northwest Corridor Express Lanes in Georgia early in the construction process. The lanes opened to traffic in September 2018.

Internet Watch

by Eric Brown

Assisting Practitioners with Hydraulic Design

The purpose of hydraulic engineering is to design a structure with the proper capacity to divert or remove water from the roadway and pass collected water under the roadway. Designing a hydraulic structure requires knowing how much water is associated with the design storm (hydrology) and calculating the velocity, depth, and type of flow (hydraulics) that must be accounted for.

To help with hydraulic design, the Federal Highway Administration's hydraulic engineering professionals work closely with a software development firm as well as partners and stakeholders at Federal, State, and local agencies to develop and advance hydrologic and hydraulic software applications. These tools perform both routine and complex calculations to improve design efficiency and reliability. One of these applications is the FHWA Hydraulic Toolbox.

The Hydraulic Toolbox is a free, publicly available, stand-alone suite of calculators that assists with analyses for the hydraulic design of transportation infrastructure.

Features of the Toolbox

Specific calculators in the Hydraulic Toolbox address a wide set of design variables and features including rational method hydrology, roadside channel capacity, channel linings, curb and gutter sections, bridge scour analysis, and culvert assessment. The program enables users to perform and save hydraulic calculations in one project file, analyze multiple scenarios, create plots, and generate reports of the analyses. The procedures available in the toolbox are based on methods published in the FHWA hydraulic engineering library of technical reference documents, known as the Hydraulic Design Series (HDS) publications, and Hydraulic Engineering Circular (HEC) publications.

The Hydraulic Toolbox has been well received by engineers, designers, and other practitioners.

"The bridge scour tools provide the New Hampshire Department of Transportation [NHDOT] with a consistent means to perform important calculations," says Timothy Mallette, a hydraulics engineer with NHDOT's Bureau of Highway Design. "The Hydraulics Toolbox is also a welcome addition to our training program for young engineers."

Increased Functionality

FHWA continues to expand the toolbox's functionality with new features. One of the latest enhancements is the bridge scour plotting tool. The scour calculator follows the procedures presented in the current (fifth) edition of HEC-18: *Evaluating Scour at Bridges* (FHWA-HIF-12-003), to assist users with analyses of abutment, pier, and contraction scour as well as long-term channel degradation. The Hydraulic Toolbox can generate a profile plot of the calculated scour components as well as the total scour elevations.

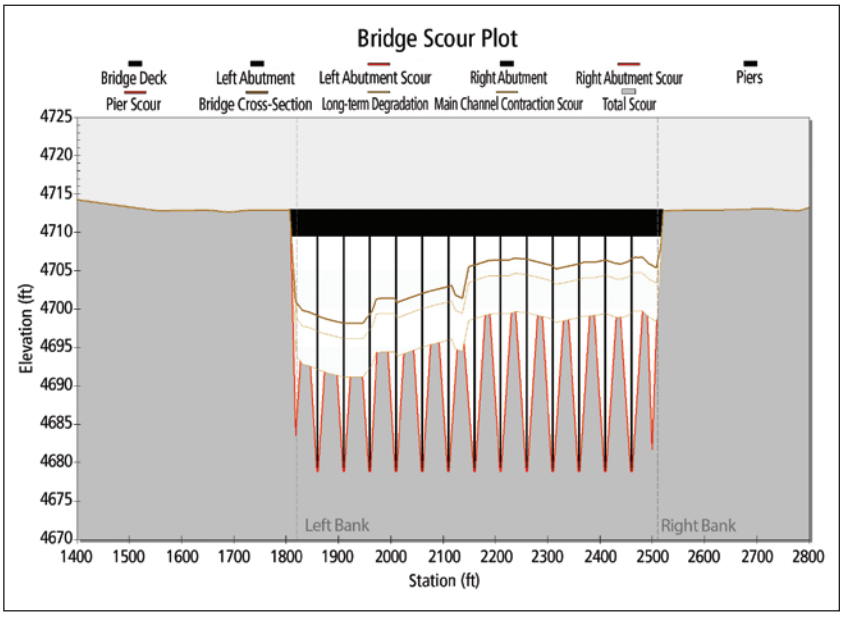
Although the Hydraulic Toolbox primarily functions as a stand-alone program, recent advances in the Surface-water Modeling System (SMS), another FHWA-sponsored hydraulics software program that performs two-dimensional flow analyses, have streamlined bridge scour calculations. SMS is now linked to the Hydraulic Toolbox scour calculator and assists users with determining the hydraulic parameters necessary for scour computations and transferring these parameters to the Hydraulic Toolbox scour calculator. Two-dimensional hydraulic modeling is included in round 5 of Every Day Counts as part of the Collaborative Hydraulics: Advancing to the Next Generation of Engineering (CHANGE) innovation. Visit www.fhwa.dot.gov/innovation/everydaycounts/edc_5/change2.cfm for more information.

Updated to version 4.4 in July 2018, the toolbox includes a *Desktop Reference Guide* with the software installation (accessible from the Help button on the top toolbar) to provide important information on the technical features, capabilities, and limitations of the calculators. In addition, the National Highway Institute offers an on-demand, web-based training course for the toolbox, course 135093. The free course takes 3 hours to complete.

The Hydraulic Toolbox, other software applications, and the complete library of HDS and HEC reference manuals are available on FHWA's website at www.fhwa.dot.gov/engineering/hydraulics.

For more information, contact Eric Brown at eric.r.brown@dot.gov.

Eric Brown is a senior hydraulic engineer on the Geotechnical and Hydraulic Engineering Team in FHWA's Resource Center.



The Hydraulic Toolbox's scour calculator can produce a scour profile plot like this one of components as well as total scour. *Source: FHWA.*

Training Update

by Judy Francis

Improving Public Safety Through Access Management

Research shows that any time roadways connect, the risks of collision, injury, and death increase. Of the approximately 6 million crashes reported in the United States each year, 55 to 75 percent are access related, meaning they occur at conflict points where vehicles, pedestrians, cyclists, and other modes cross paths or are forced to react to speed differentials. A multimodal approach to the principles, tools, and techniques collectively known as access management can improve safety and enhance mobility by reducing these conflicts.

Access management is the coordinated planning, regulation, and design of access between roadways and land development. The most fundamental purpose of access management is to support increased levels of economic activity over longer, more sustained periods of time in a way that protects public safety and ensures the efficient flow of people and goods. Proper access management accommodates both motorized and nonmotorized roadway users and protects public and private investments. Poor access management introduces higher risks and can result in increased delays, reduced efficiency, increased crash frequency, unsightly strip development, unwanted cut-through traffic, and decreased property values.

To support access management and protect public safety, the National Highway Institute (NHI) has revised its popular access management course into two new courses to incorporate updates from the second edition of the *Access Management Manual* and its companion volume, the *Access Management Applications Guide*.

Updating Existing Approaches

Access Management: Fundamental Principles and Application (course 133078) is NHI's 2-day instructor-led training on the fundamental concepts and applications of access management. NHI has redesigned the course to provide a hands-on approach for both technical and nontechnical participants, while offering a more multimodal view of the topic.

"The new course really reflects both the art and science to effectively implementing access management," says Marc Butorac, PE, PTOE, PMP, the chairman of the Transportation Research Board's Access Management Committee. "The course also successfully incorporates the latest research and reflects how all modes benefit from access management techniques and policies."

The course emphasizes accessibility and mobility, and the roles and importance of regulatory partners at all levels of government. Focusing on network completeness rather than primarily on arterial roadways, the training includes information on topics that were absent in the first edition of the *Access Management Manual*, such as performance measures and systems-based approaches.

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Property access is necessary but inherently introduces risk. Poor access management can create a "free for all" environment that may introduce safety concerns, but careful planning can improve safety and minimize conflict points.

The first day of training introduces participants to basic access management concepts, presents the effects of successful access management programs, and covers the issues associated with the prevalence and improper location of both signalized and unsignalized access points. The content of the second day addresses individual access management techniques in more detail, provides information about administering and coordinating access management programs, and shares methods of measuring the success of access management techniques and overall programs.

NHI also offers a 3-day training option, Access Management: Fundamental Principles, Application and Computation (course 133078A), for more advanced participants. The 3-day course includes all the elements of the 2-day course. During the third day, participants take a more indepth look at practical computational approaches to various access management techniques.

Engaging Learners

Instructors encourage participants in both courses to ask questions and share experiences. They use interactive technology to aid in completing case study exercises, most of which are performed in small groups. Both courses use a single case study corridor throughout, and each subsequent exercise builds on prior exercises, including the incorporation of video drone footage to provide greater understanding of the unique characteristics of the case study corridor. This approach enables participants to build on previously developed knowledge and requires application of all aspects of access management to a real-world example.

"I'm really proud of the metamorphosis of these courses," says Chris Huffman, PE, a long-time certified instructor of the course. "They offer a much more hands-on experience for the participants than previous iterations [and] have been developed with a much wider audience in mind."

For more information on this course, or to register for an upcoming session, visit www.nhi.fhwa.dot.gov.

Judy Francis is a contracted marketing analyst for NHI.

Communication Product Updates

Compiled by Lisa A. Shuler of FHWA's Office of Corporate Research, Technology, and Innovation Management

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).

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:

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Telephone: 703–605–6050
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Requests for items available from the R&T Product Distribution Center should be addressed to:

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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).

Human Factors Guidelines for Transportation Management Centers
Publication Number: FHWA-HRT-16-060

Transportation management centers (TMCs) traditionally have served as the real-time interface between motorists and transportation agencies. Rapid changes in TMCs demonstrate the need for guidance that is current, clear, practical, relevant, and easy to use. Human factors guidelines tailored to TMCs are necessary to help TMC staff appropriately consider human factors, develop accurate internal guidelines, avoid false assumptions regarding operators/drivers, and correctly apply human factors guidelines from other domains. This report presents a set of human factors guidelines to be used by organizations interested in developing, evaluating, or modifying their TMCs.

This report is divided into five chapters. The first chapter describes an operator's strengths, limitations, and biases when interfacing with technology. Chapter 2 describes how operators interact with automated systems. Chapter 3 provides an overview of TMC infrastructure, physical layout, and organizational structure and workflow, and discusses how the locations of TMC elements (onsite or offsite) affect performance. Chapter 4 describes the systems and tools used within a TMC. Chapter 5 includes information about communications with the public, colleagues, and other agencies, and addresses content and delivery mechanisms for messages along with recommendations for facilitating communication across organizations.

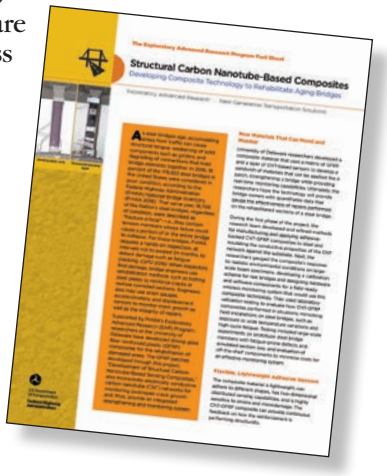
This report is geared toward practitioners and organizations interested in developing, evaluating, or modifying their TMCs.

The document is available to download at www.fhwa.dot.gov/publications/research/safety/16060/index.cfm.

Structural Carbon Nanotube-Based Composites: Developing Composite Technology to Rehabilitate Aging Bridges
Publication Number: FHWA-HRT-17-123

As steel bridges age, accumulated stress from traffic can cause structural fatigue, weakening of solid components such as girders, and degradation of connections that hold the bridge elements together. According to FHWA's National Bridge Inventory, 16 percent of the 178,923 steel bridges in the United States were considered to be in poor condition in 2016.

Supported by FHWA's Exploratory Advanced Research (EAR) Program, researchers at the University of Delaware have developed strong glass fiber reinforced plastic (GFRP) composites for the rehabilitation of damaged areas. The GFRP patch developed through this project—Development of Structural Carbon Nanotube-Based Sensing Composites—also incorporates electrically conductive carbon nanotube networks for monitoring post-repair

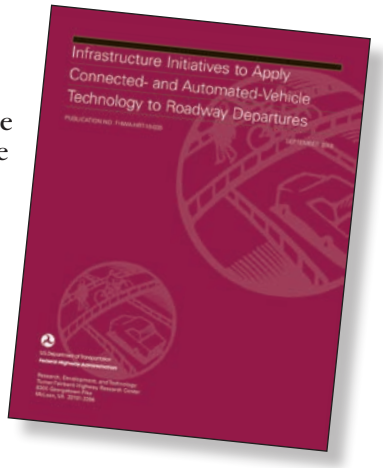


crack growth and provides an integrated strengthening and monitoring system.

The researchers developed a composite material that uses a matrix of GFRP and a layer of carbon nanotube-based sensors to form a sandwich of materials. This composite material can be applied like a patch, strengthening a bridge member while providing real-time monitoring capabilities. The researchers anticipate that the technology will provide bridge owners with quantifiable data that can gauge the effectiveness of repairs performed on the rehabilitated sections of a steel bridge.

The fact sheet is available to download at www.fhwa.dot.gov/publications/research/ear/17123/index.cfm.

Infrastructure Initiatives to Apply Connected- and Automated-Vehicle Technology to Roadway Departures (Report)
Publication Number: FHWA-HRT-18-035



FHWA is investigating how emerging connected-vehicle (CV) and automated-vehicle (AV) technologies can address roadway-departure crashes. This report addresses the effects and opportunities of widescale adoption of CV and AV technologies on the Nation's roads.

The report describes initiatives that FHWA may use to support the deployment of CV and AV technologies in ways that will address roadway departure crashes. Researchers developed the initiatives from a literature review and consultation with technology developers, vehicle manufacturers, State and local departments of transportation, and infrastructure officials.

This report is intended for traffic engineers, highway designers and planners, and other transportation professionals, to acquaint them with potential infrastructure changes that could accommodate these emerging vehicle technologies.

The document is available to download at www.fhwa.dot.gov/publications/research/safety/18035/index.cfm.

SHRP2 Traffic Incident Management Responder Training Program: Final Report
Publication Number: FHWA-HRT-18-038

FHWA has initiated an effort to evaluate programs related to research and technology (R&T). The R&T Evaluation Program helps FHWA assess how effectively it is meeting its goals and objectives and providing useful data to inform future projects. It also helps FHWA to communicate its findings and the impacts of its programs.

This final report assesses the effectiveness of the second Strategic Highway Research Program (SHRP2) Traffic Incident Management (TIM) Responder Training Program in disseminating TIM concepts to a wide incident-responder community, enhancing agency practices, and positively impacting key TIM performance metrics.

The report focuses on three areas of the SHRP2 TIM Responder Training Program: the dissemination of TIM trainings and concepts across the country, responder and agency adoption of SHRP2 TIM concepts, and improvements in key TIM performance metrics.

This report should be of interest to practitioners, researchers, and decisionmakers involved in road safety and emergency operations.

The report is available to download at www.fhwa.dot.gov/publications/research/randt/evaluations/18038/index.cfm.

Analysis Procedures for Evaluating Superheavy Load Movement on Flexible Pavements, Volume I: Final Report
Publication Number: FHWA-HRT-18-049

The movement of superheavy loads on the Nation's highways is increasingly common and a vital economic necessity for many industries, such as chemical, oil, electrical, and defense. Many superheavy components are extremely large and heavy (gross vehicle weights of more than a few million pounds), and they often require specialized trailers and hauling units. Accommodating these load movements without undue damage to highway infrastructure requires the determination of whether the pavement is structurally adequate to sustain the load and protect any underground utilities.

The goal of this project was to develop a comprehensive analysis process for evaluating superheavy load movement on flexible pavements. As part of this project, the research team developed a comprehensive mechanistic-based analysis approach consisting of several analysis procedures for flexible pavement structures, which is documented in a 10-volume series of FHWA reports. This report, *Analysis Procedures for Evaluating Superheavy Load Movement on Flexible Pavements, Volume I: Final Report*, presents a summary of the analysis procedures developed to address the critical factors associated with the movement of superheavy loads on flexible pavements.

This report is intended for use by highway agency pavement engineers responsible for assessing the structural adequacy of pavements in the proposed route and identifying mitigation strategies, where warranted, in support of State highway agencies' responses to permit requests for superheavy load movements.

The document is available to download at www.fhwa.dot.gov/publications/research/infrastructure/pavements/18049/index.cfm.

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DRIVE LIKE YOU WORK HERE

Work Zone Awareness Campaign Turns 20

This year, the Federal Highway Administration and its partners celebrate 20 years of sponsoring National Work Zone Awareness Week. The annual spring campaign, held at the start of construction season, encourages safe driving through highway work zones.

Work zones play a key role in maintaining and upgrading the Nation's roadways. Unfortunately, daily changes in traffic patterns, narrowed rights-of-way, and other construction activities often create a combination of factors resulting in crashes, injuries, and fatalities. Speed is a contributing factor in about 28 percent of fatal work zone crashes.

National Work Zone Awareness Week brings attention to the safety, mobility, and construction issues associated with work zones. The key message is for drivers to use extra caution in work zones to keep themselves and others safe. In short: **Drive like you work here.**

For resources, guidance, and training, visit the FHWA Work Zone Management website at www.fhwa.dot.gov/workzones and the National Work Zone Safety Information Clearinghouse at www.workzonesafety.org.

National Work Zone Awareness Week
April 8–12, 2019

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Federal Highway Administration
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