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MICROMOBILITY
A TRAVEL MODE INNOVATION

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COVERS and ABOVE—Emerging micromobility options, like shared e-scooter programs, offer riders new options for shorter trips and active transportation.

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Working Together to Improve Pedestrian Safety

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In 2019, traffic deaths decreased across the United States, with a fatality rate of 1.10 per 100 million vehicle miles traveled, the lowest since 2014. This is positive news, but even more encouraging is the 2.7-percent decrease in the number of pedestrian fatalities.

To lose 36,096 individuals on our Nation's roads, including 6,205 pedestrians, is still unacceptable, but given that there was a 3-percent increase in pedestrian deaths in 2018 and a 53-percent increase from the low point in 2009 until 2018, any reduction in pedestrian fatalities shows that efforts to improve safety may be starting to pay off.

As with any roadway safety challenge, it takes numerous stakeholders all doing their parts to bring results. Roadway designers, vehicle manufacturers, law enforcement, and the public all have a role to play.

One of the innovations in round 5 of the Federal Highway Administration's Every Day Counts initiative was Safe Transportation for Every Pedestrian (STEP). This innovation encouraged States and municipalities to continue to deploy proven safety countermeasures, such as rectangular rapid flashing beacons, crosswalk visibility enhancements, pedestrian hybrid beacons, and road diets. Many of these countermeasures not only improve safety, but have the added benefit of enhancing quality of life for pedestrians of all ages and all abilities at a relatively low cost. As transportation departments across the country continue to focus on pedestrian crossing locations in a systematic way, it is anticipated that there will be even greater reductions in pedestrian deaths.

The increase in the percentage of sport utility vehicles on roadways is undoubtedly one cause of the increase in pedestrian fatalities from 2009 onward. Vehicle manufacturers have been working to modify the design of vehicles to reduce the severity of crashes, despite vehicle owners continuing to favor large vehicles, which commonly pose a greater risk to pedestrians than smaller vehicles. Deploying technologies such as pedestrian crash avoidance systems is one of the most promising solutions to reduce the hazard for pedestrians. Vehicles equipped with these technologies either stop in time to prevent a pedestrian crash or slow down significantly to reduce the severity of the impact. As the deployment of these technologies expands and the technologies are refined, it will certainly lead to positive outcomes.

For our law enforcement personnel, training has been developed to help officers understand the factors associated with pedestrian crashes. The National Highway Traffic Safety Administration offers training that provides suggested enforcement strategies, but also addresses the importance of complete and accurate crash reporting. Encouraging accurate crash reporting and publishing of data not only helps roadway designers prioritize investments, but also leads to greater citizen engagement and public awareness.

Which brings us to the public and pedestrians themselves. Having a shared understanding of where and how crashes are occurring is a critical first step. Human behavior is still a primary contributing factor for crashes, so all roadway users must acknowledge that safety is a shared responsibility. Whether behind the wheel of a vehicle, riding a bicycle, or walking, we all need to be aware of our surroundings, avoid distraction, and follow the rules of the road.

Continuing to work together and all doing our part to enhance safety is the only way to move toward zero deaths on our Nation's roadways.

Victoria F. Sheehan
Commissioner
New Hampshire
Department of Transportation

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New Era, New Opportunities

by **STEPHANIE POLLACK**

Though I've only been with the Federal Highway Administration for a short time, it's already clear what an exciting time the coming year will be at FHWA and the U.S. Department of Transportation because of the central role that these agencies will play in the Biden-Harris Administration's "Build Back Better" agenda. With our local and State partners, FHWA will be critical in shaping how the Nation rebuilds highways, bridges, and streets to be better. Making sure they are safer for all users will be the foundation of a truly multimodal surface transportation system that advances the equity agenda of better connecting people to opportunity.

In my previous role as Secretary and CEO of the Massachusetts Department of Transportation, I grew to admire FHWA's important work nationwide. In that role, I was probably best known for emphasizing that transportation is not important for what it *is*—for roads and bridges, concrete and steel, or even buses and trains—but for what it *does*. It helps people and their communities succeed and prosper.

Obviously, we are in the infrastructure business—but we are also in the people business. For example, while safety will always be our most important job, we need to make sure that we focus on *everyone's* safety—drivers and passengers, of course, but also pedestrians, people in wheelchairs, cyclists, and transit passengers entering or leaving their station or stop. That's why I am so excited about U.S. Transportation Secretary Pete Buttigieg's embrace of complete streets, which are really just streets that are safe—and *feel* safe—for all users. We did a lot of great work on building complete streets in Massachusetts and I know there's more FHWA can do to ensure that streets everywhere are safe for everyone. To cite just one example, the pending changes to the *Manual on Uniform Traffic Control Devices* have the potential to empower local and State street owners to rethink how streets are signed, signaled, and marked, and how speed limits are set.

Complete streets are just one example of how the world of transportation is changing. By training, I am an engineer. By definition, engineers are problem solvers—but the problems we are asked to solve are changing. We cannot ensure that highways and bridges are well-maintained without making sure our infrastructure investments are succeeding in making transportation networks more reliable. We want to ensure those investments advance equity and help build a transportation system that works for everyone. We also want to ensure that those investments address climate change, and acknowledge that the transportation sector produces the largest and fastest growing set of greenhouse gas emissions.

As I see it, we have two problems to solve in addressing climate change. First, how to build out the infrastructure that will help decarbonize travel and, second, how to make transportation infrastructure resilient to a changing climate. With some of the world's most innovative road and bridge engineering and planning expertise, and access to important and actionable data, FHWA is the perfect place to lead on solving this more broadly defined set of transportation challenges.

I look forward to helping to ensure that America has a 21st-century transportation system that works for, and is safe for, everyone. This will be a new era with new opportunities for the agency and, together, we will continue to lead even as we face new challenges.

STEPHANIE POLLACK is FHWA's Acting Administrator.

From the Center for Accelerating Innovation

Have You Shared Your Innovation with Your Neighbor?

by **JEFFREY ZAHAREWICZ**

Sometimes the inspiration to try something innovative can come from your neighbor's proverbial backyard. Creating a neighborhood for the transportation community to share their successes was the goal of the National State Transportation Innovation Council Network Showcase (STIC Showcase), conducted as part of the Virtual Summit that launched Every Day Counts round six (EDC-6; for more information, see the Innovation Corner in the Winter 2021 issue of *Public Roads*).

The STIC Showcase provided a virtual venue to celebrate 245 innovations developed and deployed across the country that save lives, time, and resources, and created a space for the innovations to find a wider audience to expand their use and impact.

Sara Lowry, the STIC program coordinator at the Federal Highway Administration, described the call for ideas and ground rules for participation: "Working with each STIC, we solicited for innovations that were 'homegrown,' already successfully deployed, and could easily be adapted by other transportation agencies. We were truly excited by the response!"

Sharing Insights Virtually

Organized around topics such as safety, design and construction, and maintenance and emergency response, the STIC Showcase featured virtual posters that described each innovation and its benefits, along with access to supporting resources and points of contact. Summit attendees could browse through these posters at their own pace, and download and share the information with peers.

Clare Fullerton, P.E., the manager for the North Carolina Department of Transportation's Communicate Lessons, Exchange, Advice, Record (CLEAR) Program, found immediate value with this technical content. "I have saved many submissions into my 'briefcase' so that I can view them at a later date," she says. "As things come up in day-to-day work, I've gone back to the Showcase to see if another State has solved a similar issue."

Indeed, attendees were able to compare efforts from around the country on a variety of topics. For example, visitors to the safety section could learn about the wrong-way driving initiatives from the Arizona and Florida DOTs. Elsewhere, the Indiana and Mississippi DOTs each shared their approaches to saving time by conducting risk-based contract administration and inspection.

Presenting Live Panels

To complement this content, the STIC Showcase also included three live panel sessions aligned to the overarching themes of the summit: Engaging People, Deploying Products, and Improving Processes. Twenty panelists provided 6-minute pitches to pique further interest in their innovations. For Fullerton, participating on the Engaging People panel yielded that exact objective. "I have followed up with Illinois DOT, a fellow panelist, to be included in a series of interviews to collect best practices on internal innovation practices," she says. "Without the Showcase, I wouldn't have known about the work they are doing and it's been very helpful!"

Many STIC Showcase topics clearly supported the idea that communication is key to advancing innovation. Washington State DOT's "Webinar Wednesday" series, which shares information on their research projects to encourage other agencies to implement their findings, has engaged more than 3,100 participants. California DOT's virtual Innovation Expo 2020, which engaged 1,350 individuals from 13 States, conveyed the philosophy that innovation in transportation requires an ongoing commitment of all involved to pursue new ways of conducting business.

The virtual lobby of the National STIC Network Showcase enabled attendees to access a range of content from online posters to panel presentations.

Source: FHWA.

The transportation community can continue to access all of the Showcase content through December 2021 by registering for the EDC-6 Virtual Summit at *www.labroots.com/ms/virtual-event/fhwa-everyday-counts-6-virtual-summit*, and clicking on the National STIC Network Showcase button. All are encouraged to explore and learn more about an amazing variety of homegrown efforts. With 245 innovations to choose from, there is bound to be something there to inspire you…and don't forget to tell your neighbors!

JEFFREY ZAHAREWICZ is the Acting Director for the Center for Accelerating Innovation.

CARMA℠: IMPROVING TRAFFIC FLOWS AND SAFETY AT ACTIVE WORK ZONES

FHWA's CARMA℠ Program is testing how cooperative driving automation can manage work zone congestion and enhance safety.

by **PAVLE BUJANOVIĆ, TODD PETERSON,** and **DENISE BAKAR**

Developed by the Federal Highway Administration, the CARMA℠ Program is leading research on the information exchanges and cooperative maneuvers that constitute cooperative driving automation (CDA). Defined by the Society of Automotive Engineers J3216 Standard, CDA aims to improve the safety, flow, and efficiency of roadway infrastructure by supporting the cooperative movement of automated vehicles through the use of wireless mobility applications. Through software development activities, the program is building numerous CDA features (or applications) that will be tested in a set of research tracks focused on transportation systems management and operations. The research tracks aim to demonstrate the potential of CDA to facilitate system efficiency and safety improvements in various areas of the transportation ecosystem.

The work zone management (WZM) use case is part of the CARMA Reliability research track. This research track examines solutions to nonrecurring congestion on freeways and arterials, such as traffic incidents and inclement weather, in addition to work zone activity. The WZM use case will demonstrate the role of CDA in improving safety and alleviating work zone-related congestion. The program is addressing multiple WZM scenarios, with each scenario demonstrating improved network performance through the application of a specific CDA feature.

"The application of CDA to work zone management has been among the most challenging cases for automated vehicle operations. The CARMA WZM use case lays a foundation for addressing this challenge, which is critical to expanding the applicability of CDA to other environments," says Dr. Xiaopeng Li, an associate professor at the University of South Florida and director of the National Institute for Congestion Reduction, whose team is developing CDA algorithms that will be tested in the CARMA ecosystem.

The Work Zone Scenario

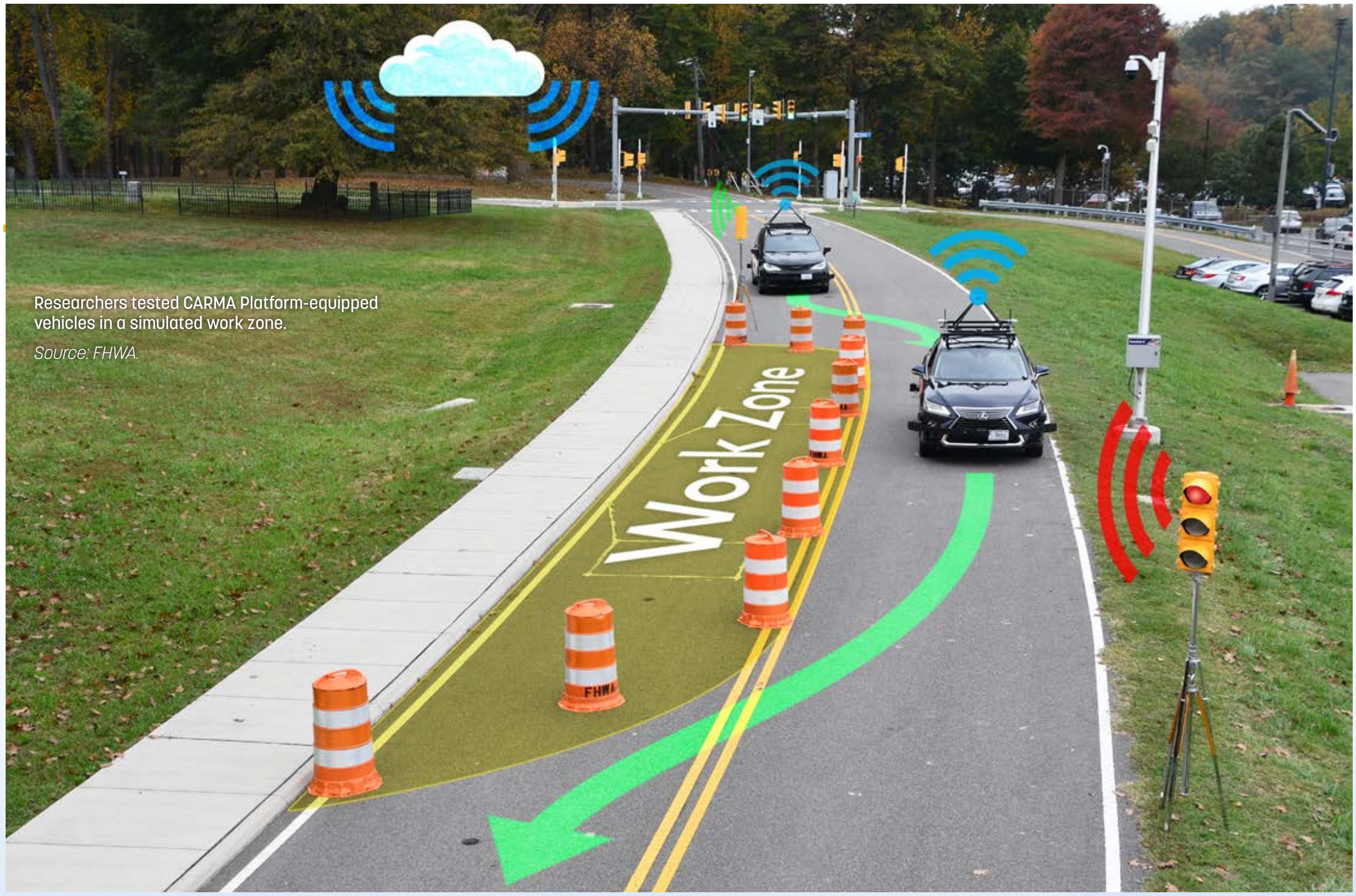
The first scenario developed under the WZM use case involves a one-lane, two-way traffic taper resulting from an active work zone on a two-lane arterial street. This scenario calls for an active work zone to occupy a segment of one lane, requiring vehicles equipped with a cooperative automated driving system (C-ADS) to temporarily merge into the lane traveling in the opposite direction to pass the work zone lane closure. To accomplish this, the vehicles must communicate with CARMA Cloud℠ and CARMA Streets to ensure that it is safe for them to enter the work zone. Vehicles are equipped with C-ADS technology through the installation of CARMA Platform℠, which bestows the Society of Automotive Engineers ADS Level 3+ functionality.

The work zone scenario proceeds as follows: The vehicles equipped with C-ADS are traveling on a two-lane arterial that contains a work zone. At one section in the arterial, one of the lanes is closed. Stationed at either end of the work zone are two temporary traffic signals; the traffic signals are synchronized and have fixed timing to allow only one direction of traffic to proceed through the work zone at a time. A future application will explore use of adaptive traffic signal timing based on the presence of vehicles in each direction.

The vehicles regularly transmit location information, via their onboard units, to CARMA Cloud through V2X

FHWA's fleet of vehicles equipped with the CARMA Platform are helping researchers test how cooperative driving automation can relieve work zone congestion and improve safety.

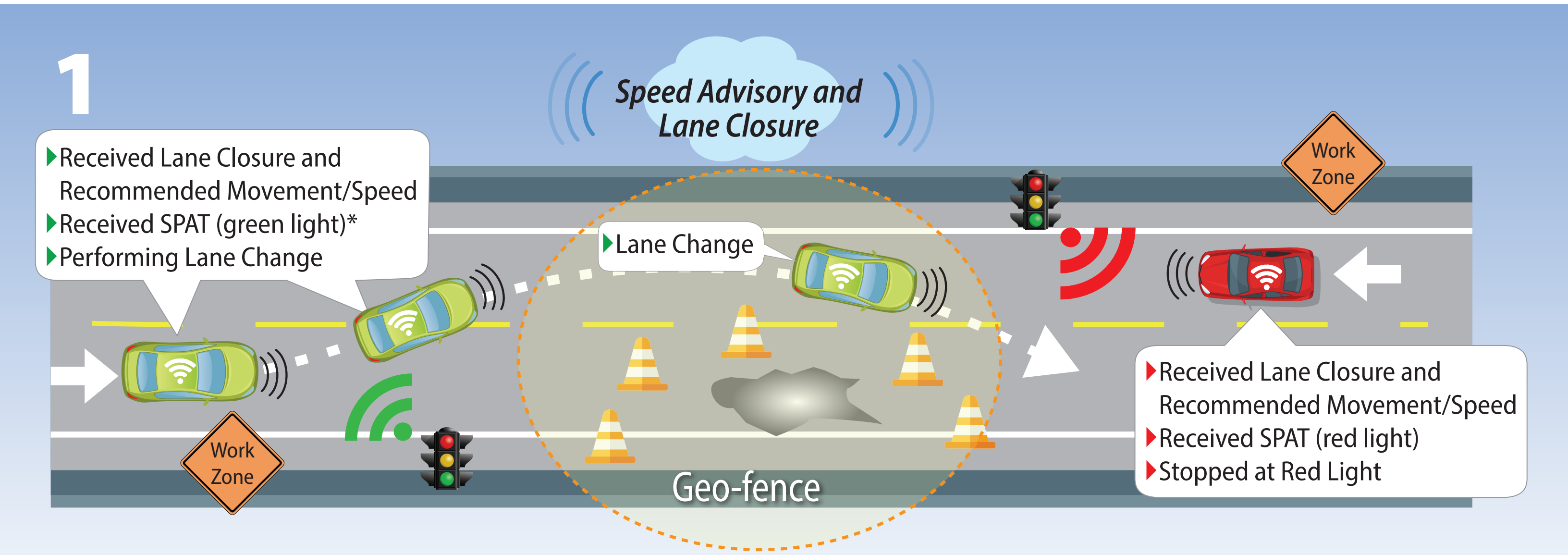
Source: FHWA.



Researchers tested CARMA Platform-equipped vehicles in a simulated work zone.
Source: FHWA.

[vehicle-to-everything] Hub. V2X Hub is a separate, multimodal open-source software system, stored in roadside infrastructure such as traffic cabinets, which enables networked, wireless communications between participating entities. As the vehicles approach the traffic signals near the work zone, CARMA Cloud prepares a message containing information about the work zone lane closure in the intended direction of the vehicles. The message identifies the virtual perimeter (geofence) for the work zone and contains recommended movement information for vehicles traveling through the geofence—this includes a low speed advisory and alternative lane geometry. CARMA Cloud transmits the message to V2X Hub for broadcast to the approaching vehicles. The vehicles receive the message via their individual onboard units.

Traffic signals deployed on either end of the work zone control traffic movement in the work zone. For example, the vehicles in the lane with the closure receive the traffic green light to proceed, while the vehicles in the opposite lane remain stopped at a red light. The moving vehicles use the



The first work zone management use case involves a one-lane, two-way traffic taper. Vehicles traveling on the side of the road blocked by the work zone must merge into the lane traveling in the opposite direction.

*SPAT is defined as Signal Phase and Timing.

Source: FHWA.

recommended movement information from CARMA Cloud to cross the yellow line separating the travel lanes, merge to the opposite lane, travel at the advised speed through the work zone, and merge back into their original lane after clearing the geofenced area.

Once the traffic signal in the closed lane changes to red, there will be a brief "all red" period during which both directions face a red signal. This ensures that there are no vehicles still passing through the work zone when the opposite direction receives a green signal. After this brief period, the vehicles in the open lane receive a green signal to proceed through the work zone. The moving vehicles reduce their speed to meet the low speed advisory and drive through the work zone area. After passing through the work zone and exiting the geofenced area, vehicles in both directions continue to travel in their respective lanes at the posted speed limit.

This traffic control pattern continues for the duration of the lane closure due to the active work zone.

To direct the safe passage of vehicles through active work zones, the scenario employs the Work Zone Data Exchange message specification, which leverages cloud services to facilitate information exchanges between vehicles, infrastructure, and road users. To ensure that the features operate safely and in the way they were designed for this specific operational design domain, the CARMA team conducted functional tests prior to validation testing of the CDA features required for the scenario.

Collaboration

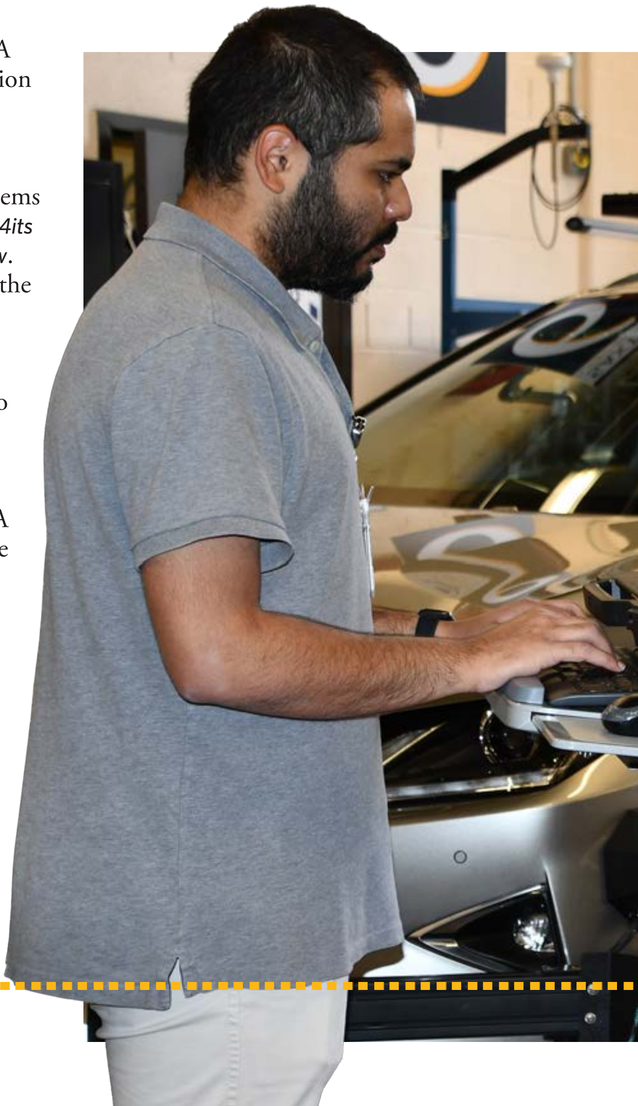
The CARMA Program leverages collaboration with stakeholders in government, academia, consulting, and the technical industry to accelerate advancements in CDA research, development, and testing. The program's CARMA Collaborative effort teamwork through multiple touchpoints, from webinars and group meetings to conferences and panels. CARMA products, which are open for collaboration on the GitHub development platform (*https://github.com/usdot-fhwa-stol*), are included in the Open Source Software Suite for Intelligent Transportation Systems (OSS4ITS), available at *https://usdot-oss4its.atlassian.net/wiki/spaces/OSSFITS/overview*. Deployers can use, reuse, and augment the tools to help accelerate their programs.

Looking Ahead

The introduction of CDA is expected to produce numerous positive impacts to the movement of people and goods on the Nation's roads. The WZM use case establishes the framework of using CDA features in active work zone areas to ease congestion and enhance traveler and worker safety.

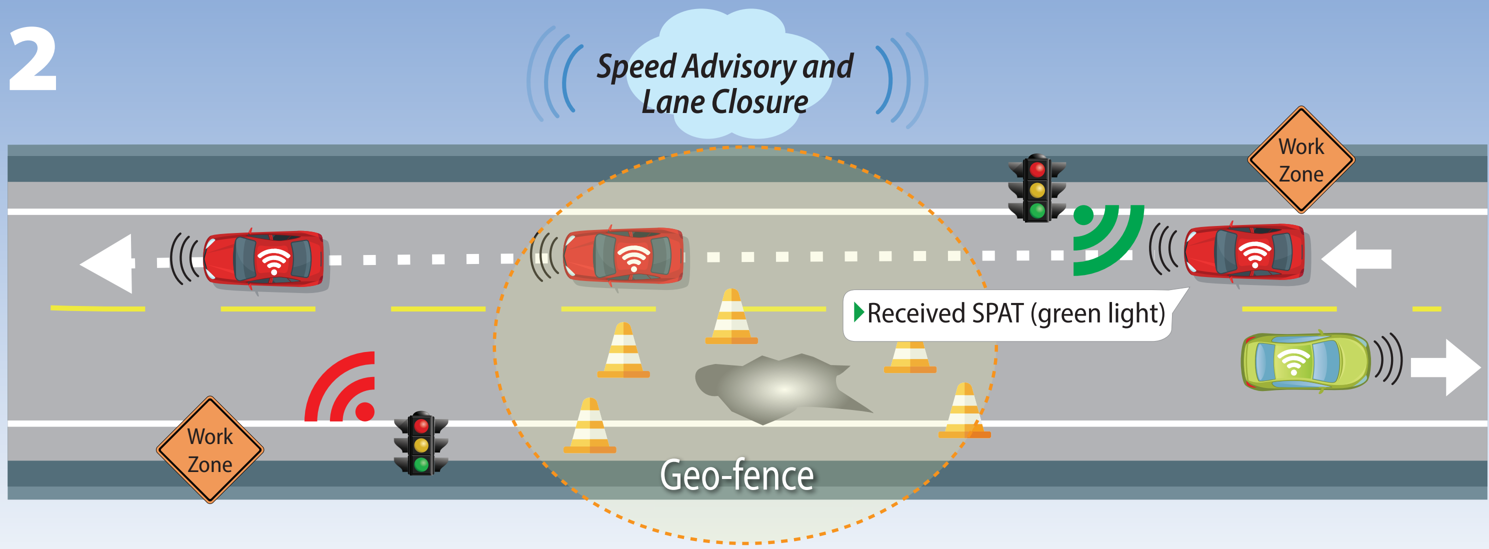
"Better communication between vehicles and work zone safety devices through CARMA will improve safety and vehicle performance though roadway work zone installations, making it safer for workers as well as motorists," says David Rush, manager of the Work Zone Safety Program at the Virginia Department of Transportation.

The WZM use case highlights the enhanced response actions—made possible through CDA—to traffic disruptions caused



An engineer performs CDA research using a CARMA Platform-equipped vehicle at the FHWA Saxton Transportation Operations Laboratory.

Source: FHWA.



by work zones. These enhanced response actions, which include improved awareness and coordinated movements of vehicles in a work zone, will ultimately lead to improvements in traffic performance by reducing congestion and incident occurrence in work zones.

"Ultimately, the success of testing will bring the Nation one step closer to deploying CDA-based transportation systems management and operations strategies for managing work zone traffic," says Barb Wendling, chair of the newly formed Society of Automotive Engineers Cooperative Driving Automation System Committee.

PAVLE BUJANOVIĆ is a CARMA technical manager in FHWA's Office of Operations Research and Development, managing various CDA research projects and leading the new CARMA Reliability research track that includes work zones. He earned a B.S. in civil engineering from Syracuse University, an M.S. in sustainable design and construction from Stanford University, and a Ph.D. in transportation engineering from the University of Texas at Austin.

TODD PETERSON is a transportation specialist for the Office of Operations' Work Zone Management Program. Todd leads FHWA's Work Zone Data Initiative, which has produced a data specification and national deployment framework for real-time information pertaining to work zone activity, and is currently leading a project to expand that effort to other nonrecurring events. He earned a B.S. and an M.S. in civil engineering from Virginia Tech.

DENISE BAKAR is a contracted communications specialist in FHWA's Saxton Transportation Operations Laboratory, leading content strategy and outreach activities. She earned an M.A. in strategic communications from American University and a B.A. from the University of Virginia.

For more background on CARMA, see "CARMA℠: Driving Innovation" in the Winter 2020 issue of *Public Roads*.

MICROMOBILITY: A TRAVEL MODE INNOVATION

With increased growth in bikeshare and shared e-scooter systems, FHWA and USDOT are helping State DOTs and cities manage micromobility deployment, and are monitoring trends and evaluating facilities and design needs.

Micromobility options like e-scooters and bikesharing remain a growing trend in the United States.
© Laura Sandt, Pedestrian and Bicycle Information Center (PBIC).

by **JEFF PRICE, DANIELLE BLACKSHEAR, WESLEY BLOUNT, JR.,** and **LAURA SANDT**

Micromobility has rapidly proliferated in cities nationwide, proving to be a popular transportation option for many users. In response to the increasing demand for walking and bicycling facilities in cities and towns across the country, many jurisdictions are exploring micromobility as an alternative mode for short trips and active transportation.

Because micromobility is still a relatively new and emerging mobility option, there are various definitions in use of what constitutes "micromobility." Building upon the Society of Automotive Engineers International's *Taxonomy and Classification of Powered Micromobility Vehicles*, the Federal Highway Administration broadly defines micromobility as any small, low-speed, human- or electric-powered transportation device, including bicycles, scooters, electric-assist bicycles, electric scooters (e-scooters), and other small, lightweight, wheeled conveyances. Other definitions of micromobility focus primarily on powered micromobility devices and characterize these devices as partially or fully motorized, low-speed (typically less than 30 miles [48 kilometers] per hour), and small size (typically less than 500 pounds [230 kilograms] and less than 3 feet [1 meter] wide).

As of August 2020, there are more than 260 shared micromobility systems, including docked and dockless bikeshare and e-scooter systems, in the United States, and the largest of these shared systems include several thousand micromobility devices. According to a recent National Association of City Transportation Officials (NACTO) report, users took 136 million trips in 2019 on shared micromobility systems, a 60 percent increase from 2018. The report is available at *https://nacto.org/shared-micromobility-2019*.

Although micromobility devices may be individually owned, the recent surge of devices in cities is due primarily to the deployment of shared fleets by private companies. Shared micromobility systems are deployed in targeted service areas with the usage generally intended for short trips such as "first- and last-mile" connections to complete trips made via other modes, including transit. Shared fleets provide users with on-demand access to devices. These fleets are most commonly parked in the public right-of-way, either grouped at a dock or as dockless devices. Users typically unlock the devices using a smartphone application or key fob.

FHWA Initiatives

In late 2018, the FHWA Office of Planning, Environment, and Realty (HEP) began efforts to gather information and set the stage for future FHWA micromobility research and exploration. With support from the U.S. Department of Transportation Volpe Center (Volpe), HEP interviewed 25 staff across 11 FHWA offices to establish FHWA's definition of micromobility; consider Federal, State, and local roles in this emerging area; and develop questions for future research. As internal expertise grew, HEP expanded coordination efforts to establish an internal USDOT micromobility working group that comprised staff from FHWA, Volpe, the Office of the Secretary, the Federal Transit Administration, the National Highway Traffic Safety Administration, and the Intelligent Transportation Systems Joint Program Office. The working group meets quarterly to track micromobility research and activities across the Department and provides a forum for exchange and discussion to maintain a coordinated approach. FHWA also coordinates micromobility topics through internal Mobility Innovation and Mobility on Demand working groups, which facilitate the coordination of current and future mobility research.

Through a cooperative agreement with the Pedestrian and Bicycle Information Center (PBIC), FHWA has supported extensive outreach and coordination with a variety of external partners. For example, PBIC staff were among the first to present on micromobility at the Transportation Research Board (TRB) Annual Meeting in January 2019, sharing research and data needs. PBIC and its subcontractor, the Institute of Transportation Engineers (ITE), partnered to host a half-day workshop at ITE's Annual Meeting in July 2019, engaging more than 45 participants from around the country in a micromobility tour around Austin, TX, and a meet-and-greet with several micromobility operators to try out their devices. In late 2019, FHWA coordinated with PBIC to produce two information briefs—*The Basics of Micromobility and Related Motorized Devices for Personal Transport* and *E-Scooter Management in Midsized Cities in the United States*—and develop a curated set of resources on its website at *www.pedbikeinfo.org/topics/micromobility.cfm*.

To better understand the impact of micromobility on the transportation network, FHWA is coordinating with public and private sector stakeholders to explore ways to aid the research and deployment of innovative multimodal travel options that will be safer and more efficient for all multimodal device users. FHWA regularly participates in coordination meetings and virtual conferences held by the American Public Transportation Association's Integrated Mobility and Communities Consortium, TRB's Mobility Management Committee and Research and Technology Coordinating Committee, and the North American Bikeshare Association.

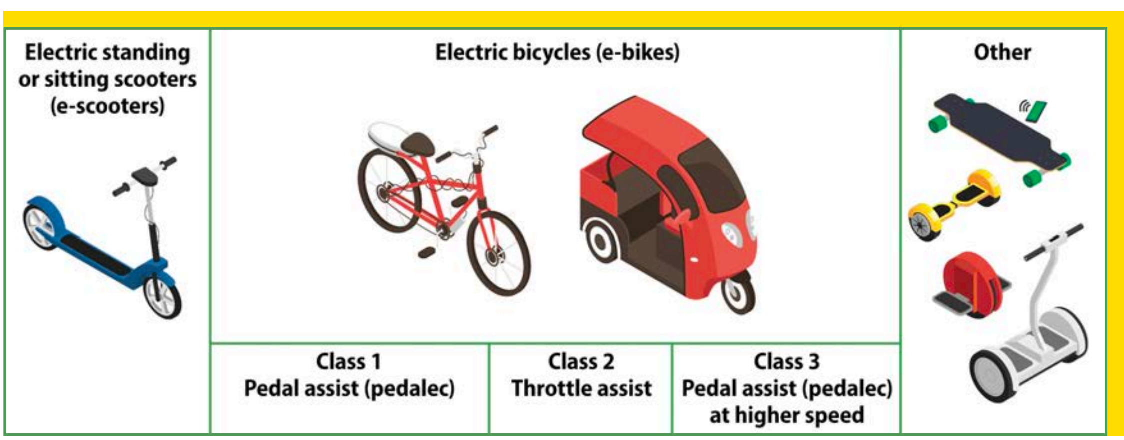
Additionally, FHWA supports the micromobility efforts of other Federal agencies, such as supporting the National Science Foundation's Smart and Connected Communities Program and participating in reviews of transportation-related projects, participating in the National Park Service's Emerging Mobility Working Group to exchange information on the state of the practice and ongoing micromobility activities, and presenting during the Consumer Product Safety Commission's Micromobility Forum Webinar, an event to discuss micromobility safety considerations in research, data, standards, and policy. In early 2020, HEP also interviewed 27 staff from 9 Federal agencies—including the U.S. Department of Energy and Centers for Disease Control and Prevention in addition to those previously mentioned—to share micromobility research activities and help identify potential gaps in research.

Based on feedback received during various outreach activities, FHWA developed a micromobility fact sheet (available at *www.fhwa.dot.gov/livability/fact_sheets/mm_fact_sheet.cfm*) and two USDOT and FHWA micromobility handouts (available at *www.fhwa.dot.gov/livability/resources/#micro*) to communicate FHWA's ongoing micromobility research and coordination activities.

Community Experiences

Micromobility devices and shared systems offer new and powerful ways to help people meet their transportation needs. E-bikes and e-scooters can help many people overcome barriers that would otherwise prevent them from taking active forms of transportation. At the same time, there is a need to be mindful of who benefits from these systems, who may be harmed or excluded, and how micromobility systems can be designed to meet their full potential in supporting safe, equitable, and resilient communities.

A 2019 report produced for the New Jersey Department of Transportation and FHWA, *E-Scooter Programs: Current State of Practice in U.S. Cities*, notes that "E-scooters are an important transportation alternative for first mile/last mile trips, for



Examples of powered micromobility devices and their classifications according to PBIC.

© Laura Sandt, PBIC.

neighborhoods underserved by conventional transit systems, and for individuals who do not own or have access to cars. Dockless e-scooter share programs, with the sensible equity policies, lend themselves to serving disadvantaged communities." The report is available at *http://njbikeped.org/wp-content/uploads/BPRC-E-Scooter-Study-2-2020.pdf*.

Cities are experimenting with a range of approaches to actively manage micromobility programs to ensure positive safety and equity outcomes. Cities are examining the effects of various safety practices—including how to set service areas, determine maximum safe micromobility device speeds, and restrict vehicle speeds or times of operation in areas with dense micromobility ridership—and exploring approaches to incentivize helmet use.

Cities also are investigating micromobility parking needs in relation to concerns about sidewalk accessibility for pedestrians with disabilities. For a deeper dive into parking management practices in Austin, see the July 2020 issue of FHWA's "Fostering Multimodal Connectivity Newsletter."

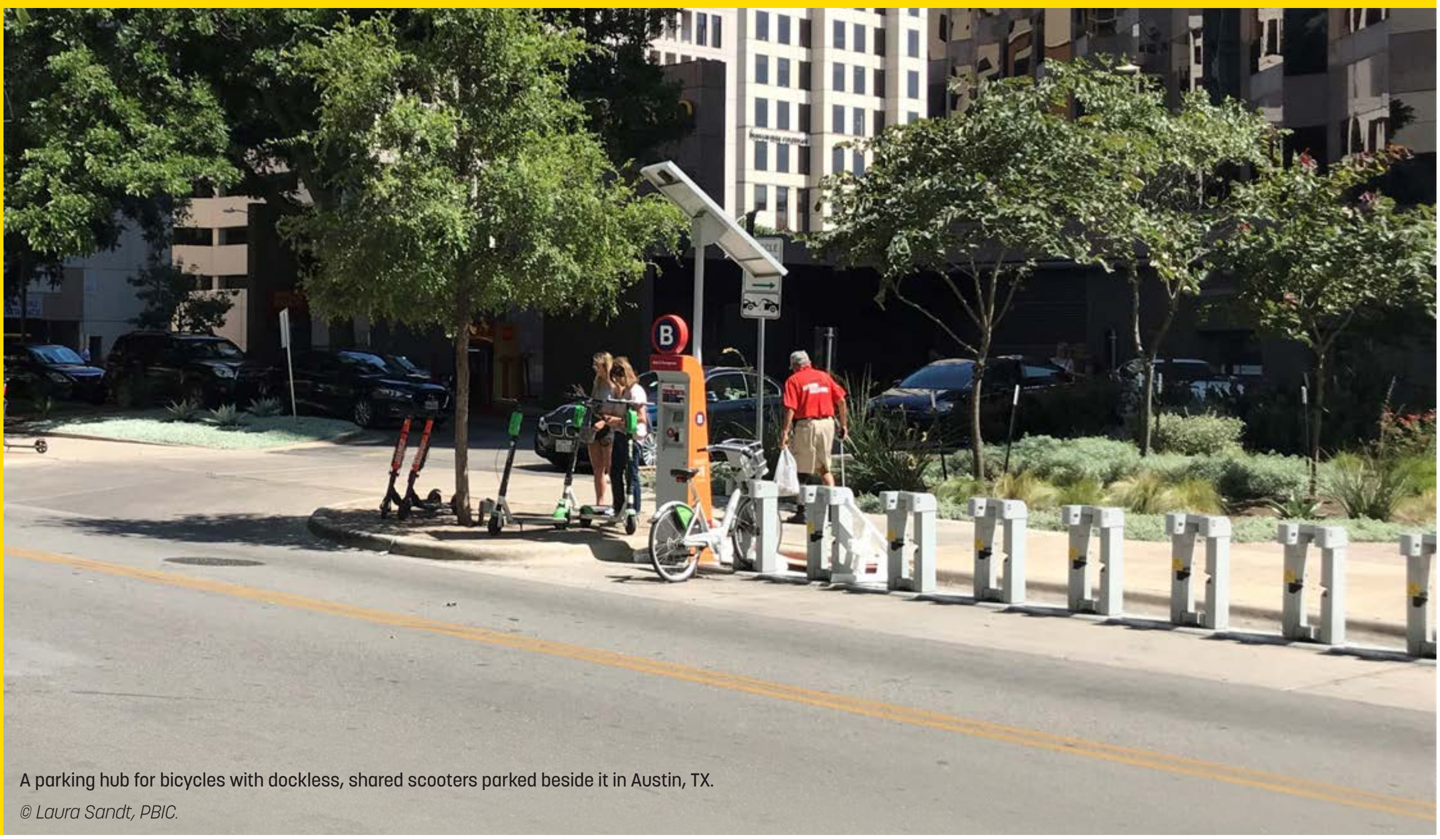
Communities are regularly engaging the public, and many are seeking to build a culture of safety through micromobility ambassador programs, rider training, and programs designed to support safe tourism and micromobility use during special events and festivals. By building program evaluation plans, conducting pilot studies, establishing data requirements and data use agreements, and partnering with diverse agencies, communities are beginning to develop protocols and training for injury reporting and incident management and learning about how to improve the safety of all road users. In many places, agencies are creating cross-departmental coordination teams, developing new funding streams, and supporting the implementation of new roadway infrastructure, operations, and parking spaces to support micromobility.

Noteworthy local highlights include:

- Phoenix, AZ: Through a pilot program, Phoenix is allowing e-scooters in its downtown area and is aiming to control usage, distribution, and parking through geofencing and clear signage and maps during the pilot phase. The city is conducting an extensive safety and ridership data evaluation.
- Denver, CO: Denver is evaluating e-scooters' ability to help achieve reductions in single-occupancy vehicle mode share goals. The city and county of Denver's micromobility pilot flows through their Transit Amenity Program, which encourages connections to public transportation.
- Portland, OR: Portland has been considered a leader in conducting robust evaluations of its e-scooter pilot program and putting into place programs to support the Portland Bureau of Transportation's equity and accessibility goals.

The city of Santa Monica, CA, is one of the longest-running examples in the United States of successfully incorporating micromobility into the community's shared mobility program. Santa Monica is a coastal city west of downtown Los Angeles with a population of roughly 91,000 people. The city is a leader in sustainable mobility, and was the first in Los Angeles County to launch a municipally owned and operated bicycle share system in 2015.

Shared micromobility devices such as bicycles, electric bicycles (e-bicycles), and e-scooters may create a more diverse, convenient, and accessible transportation network, which can provide more



A parking hub for bicycles with dockless, shared scooters parked beside it in Austin, TX.
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transportation options, reduce congestion, and improve quality of life.

Santa Monica strengthened administrative language regarding equitable access to these devices. For example, device operators must establish and promote low-income qualified rates for shared mobility device use and offer incentives (such as education, outreach, and payment plans) for low-income or other disadvantaged users. For more information, see *www.fhwa.dot.gov/livability/case_studies/santa_monica*.

In August 2020, the city of Chicago, IL, launched its second scooter pilot program with a particular focus on communities without equitable access to transportation. "This new scooter pilot program builds on our experience in the first pilot, focuses on safety for scooter riders and the general public, and requires a more equitable distribution of scooters," said Chicago Department of Transportation Commissioner Gia Biagi in a press release announcing the program. "Particularly during [this] public health crisis, it's important that we explore innovative options that make it easier for Chicagoans to get around."

The *E-Scooter Programs: Current State of Practice in U.S. Cities* report highlights practices from 11 different micromobility programs and examines the way in which equity, safety, and other considerations were integrated into various aspects of the programs. For additional indepth case studies, pilot program evaluations, and resources, visit PBIC's Micromobility topics page at *www.pedbikeinfo.org/topics/micromobility.cfm*.

Considerations for Wider Use and Adoption

While the majority of e-scooter trips end without incident, much work remains to be done to improve comfort and safety for e-scooter riders with different levels of experience, training, and travel needs. A tracker of e-scooter fatalities, maintained by the University of North Carolina's Highway Safety Research Center, shows that 20 of the 24 e-scooter fatalities in the United States involved motor vehicles, including some heavier vehicles and trucks.

In light of the potential for safety concerns, the Governor's Highway Safety Association produced a report that extensively discusses the needs around speed management, education, improved roadway design, and other community engagement essentials to help mitigate risks for vulnerable road users. *Shared Micromobility in the U.S.: 2019*—a report by the National Association of City Transportation Officials—and other research studies on shared micromobility echo these findings, calling for more attention to the need for a connected network of facilities dedicated to serving micromobility.

Looking Ahead: Research and Collaboration

Regulation and management of micromobility occurs primarily at State and local government levels. Current Federal law (23 U.S.C. 217(h)) prohibits motorized vehicles from nonmotorized trails and pedestrian walkways that use Federal highway funds (with limited exceptions for maintenance, snowmobiles, motorized wheelchairs, and electric bicycles as defined in 23 U.S.C. 217(j)(2)) and from nonmotorized trails that use Recreational Trails Program funds under 23 U.S.C. 206 (except for motorized wheelchairs). There are no Federal prohibitions for micromobility vehicles using roadways or trails open for motorized use.

Some cities are exploring how to incentivize helmet use to improve the safety of micromobility transportation.

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State legislatures and transportation departments are actively working to define lightweight vehicles and operating conditions for e-scooters, e-bikes, and other emerging dockless mobility technologies. USDOT is helping State transportation agencies and cities manage micromobility deployment through various activities such as coordinating and conducting research, developing resources and case studies, incentivizing innovative and accessible mobility through pilots and deployments, and gathering information and data on micromobility safety issues to help reduce fatalities and serious injuries.

FHWA is exploring research opportunities to support micromobility. The near-term goal is to focus on five high-priority micromobility research areas: safety, equity, resiliency, user behavior, and curbside management. These topics were identified through existing research scans, interviews with relevant FHWA staff and subject matter experts, and input from members of the USDOT Micromobility Working Group convened by the Office of Human Environment. That office intends to continue coordination and collaboration with other FHWA offices and USDOT operating administrations in developing these research topics into formal research needs statements, identifying funding, and coordinating research implementation.

"FHWA and USDOT are well positioned now to expand coordination and collaboration efforts with universities, the private sector, and other domestic and international stakeholders to monitor trends and evaluate facilities and design needs," says Gloria M. Shepherd, the Associate Administrator for Planning, Environment, and Realty at FHWA.

This national capacity building effort will aid in future review of legislation and policy development to accommodate micromobility in the Nation's evolving multimodal transportation system.

Bicyclists and e-scooter riders use a separated bike lane in Austin, TX.
© Laura Sandt, PBIC.

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FOCUSING ON PEDESTRIAN SAFETY

FHWA and other agencies across USDOT are continually addressing safety concerns for pedestrians by developing and researching effective tools and countermeasures and by coordinating projects, plans, and discussions with State and local officials and safety advocates.

This midblock crosswalk includes many STEP features including a high-visibility crosswalk, a pedestrian refuge island, lighting, and signage.

Source: FHWA.

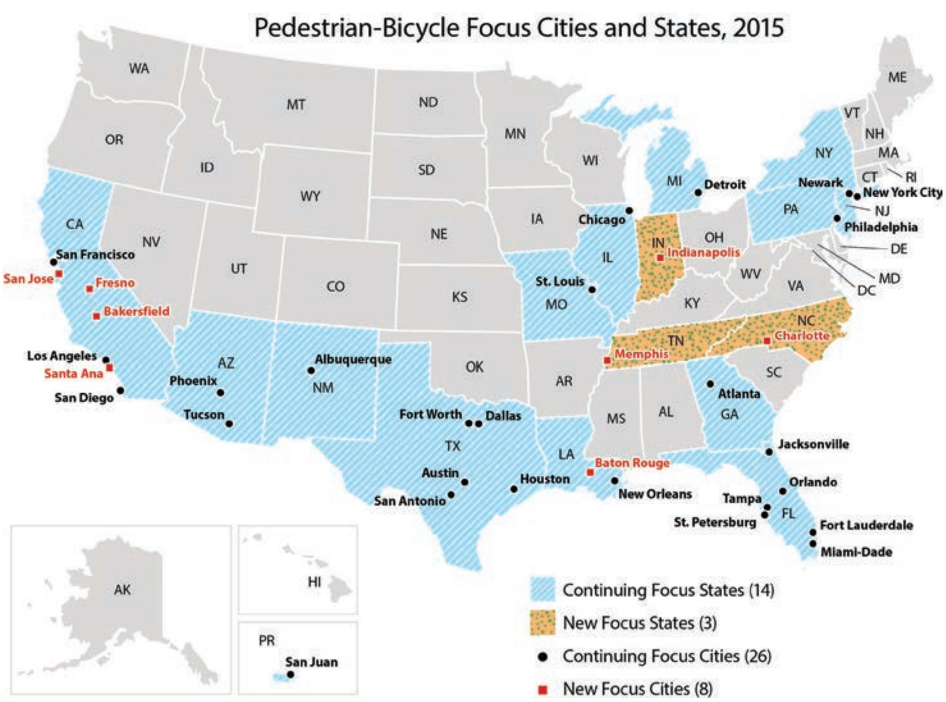
by **TAMARA REDMON, ANN DO, REBECCA T. CROWE, DARREN BUCK,** and **MICHAEL S. GRIFFITH**

In 2019, pedestrian fatalities decreased by almost 3 percent from 2018 figures, according to estimates from the National Highway Traffic Safety Administration. This is good news, particularly because pedestrian fatalities had risen in recent years, both in number and in percentage of all highway mortalities. In 2018, 6,283 pedestrians died from roadway crashes, the highest toll since 1990, and from 2009 to 2018, pedestrian fatalities in crashes increased 53 percent, and the pedestrian share of all highway fatalities increased 42 percent.

NHTSA will be working tirelessly to continue the recent downward trend, and pedestrian safety also remains a big concern of the Federal Highway Administration. FHWA's Office of Safety; Office of Safety Research and Development (R&D); Office of Planning, Environment, and Realty; and Resource Center Safety and Design Team are undertaking a series of activities that will help increase pedestrian safety.

Collaborative Efforts: Office of Safety, Office of Safety R&D, and Resource Center

Pedestrian safety is a priority of FHWA and has been a focus area since 2004. One of the ways the agency is leveraging resources is by concentrating on the States and cities with the highest pedestrian and bicyclist fatalities. The 17 States and 34 cities that have the most pedestrian and bicyclist fatalities receive technical assistance with safe facility design, data analysis and action plan development, training, and support for a wide range of analysis tools and countermeasures. FHWA reviews and revises the focus areas and data every 5 years or so.



Source: FHWA.

A midblock crossing with rectangular rapid flashing beacons.
Source: FHWA.

Technical Assistance

FHWA has developed a number of trainings, with well over 300 courses delivered and more than 6,000 people trained. In addition, FHWA offers popular quarterly webinars that consistently host 500 attendees. On top of providing training on the design of safe facilities, assisting with crash analysis, and extending specialized technical assistance, FHWA has helped many of the States and cities develop pedestrian safety action plans. Among other accomplishments, FHWA developed the *New York State Pedestrian Safety Action Plan*, which won the 2018 Governor's Highway Safety Award and helped lead the State to a large drop in fatalities.

STEP Up to Safety

The FHWA Safe Transportation for Every Pedestrian (STEP) program, an innovation of Every Day Counts, began in 2017 with a goal of helping State and local agencies reduce pedestrian fatalities at roadway crossings. The STEP program promotes the "spectacular seven" countermeasures to improve pedestrian safety at crossings: crosswalk visibility enhancements; raised crosswalks; pedestrian refuge islands; rectangular rapid flashing beacons; pedestrian hybrid beacons (PHBs); road diets; and leading pedestrian intervals. STEP has documented more than 30 case studies that highlight the safety benefits of each of the countermeasures.

PHBs constitute one of the most effective countermeasures for multilane and higher speed roads, as highlighted by case studies in Florida and North Carolina. The Florida Department of Transportation (FDOT) installed multiple PHBs along a corridor in Tampa.

"The initial crash reduction we've seen on East Hillsborough Avenue has been very encouraging," says Alex Henry of FDOT District 7. "I think it is proof positive that a combination of relatively inexpensive and easy-to-implement countermeasures can help to make an impact on even our most challenging corridors."

FHWA recently released STEP Studio, a toolbox for selecting and implementing countermeasures for improving pedestrian

A pedestrian uses a pedestrian hybrid beacon at a midblock trail crossing.
Source: FHWA.

crossing safety. STEP Studio is a visual and interactive resource that follows the steps outlined in FHWA's *Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations* (FHWA-SA-17-072) to identify potential countermeasures for a variety of contexts.

FHWA is challenging agencies to "STEP UP" to implement proven safety countermeasures at pedestrian crossings. FHWA kicked off the STEP UP campaign in summer 2020—focusing on pedestrian crossing safety in dark conditions, between intersections, and involving older pedestrians. The STEP program recently learned that the city of Roanoke, VA, installed leading pedestrian intervals across its downtown area in summer 2020.

The STEP program provides technical assistance to agencies across the United States and has produced a variety of educational resources, such as tech sheets and videos, to promote the "spectacular seven" countermeasures. The STEP team has worked with dozens of States to develop near-term action plans and conduct road safety audits. The STEP team continues to work on additional videos to explain the relationship between speed, visibility, and pedestrian safety, and the team developed a set of lesson plans for youth between kindergarten and eighth grade that will help students learn about pedestrian safety through STEM (science, technology, engineering, and mathematics).

For the latest on the STEP program, visit *https://safety.fhwa.dot.gov/ped_bike/step*.

Pedestrian crossing sign with embedded LEDs.
© Texas A&M Transportation Institute.

Global Benchmarking

FHWA is undertaking a global benchmarking study on reducing pedestrian fatalities though planning and application of safety strategies on principal (nonfreeway) and minor arterials. The goal of the study is to identify successful practices, policies, and innovations that could be applied in the United States to make existing and planned urban signalized arterials safer for pedestrians, as most U.S. pedestrian fatalities occur on arterials, especially under dark conditions.

The primary function of an urban arterial is to deliver traffic from collector roads to freeways or expressways, and between urban areas at the highest level of service possible. These roads generally have faster moving traffic and more vehicle lanes. They prioritize vehicle movement over pedestrian mobility and often lack convenient crossing opportunities.

FHWA's global benchmarking study is very timely to address the pedestrian safety crisis by (1) learning from the success of other countries that have been successful in reducing pedestrian fatalities on urban arterials; (2) identifying practices and policies that could be applied in the United States to achieve similar results; and (3) systemically implementing the findings throughout the transportation cycle within State and local highway agencies and metropolitan planning organizations.

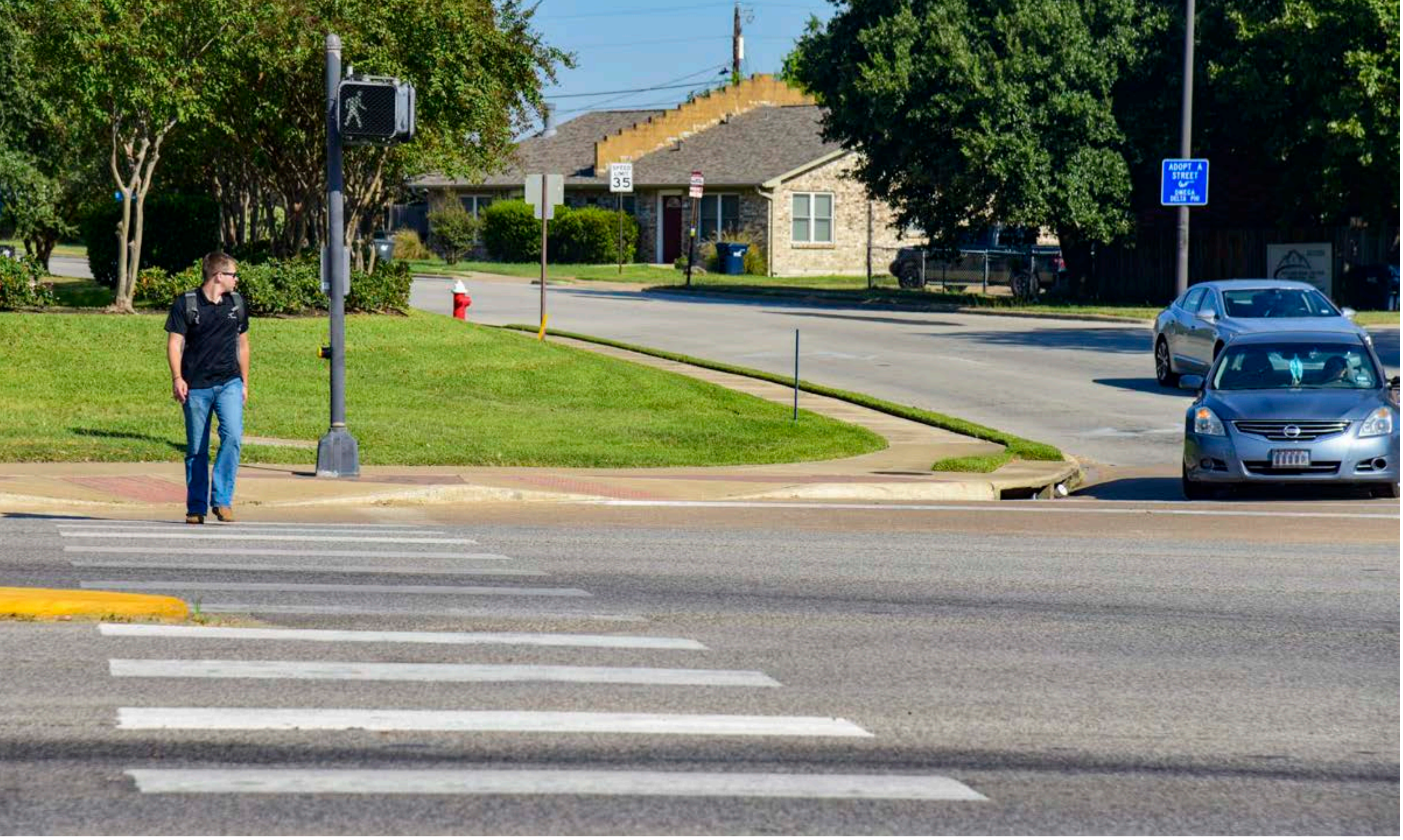
Strategic Planning

Finally, the FHWA Office of Safety recently completed a project to develop a Pedestrian and Bicyclist Safety Strategic Plan. The plan is an update to the 2010 *Pedestrian Safety Strategic Plan* (FHWA-SA-10-035) to provide FHWA's Pedestrian and Bicycle Safety program direction for the next 5 to 10 years. The plan augments the initial program and plan to include the bicycle mode and integrate the latest state of practice on multimodal safety into a "big picture" guiding vision with the ultimate objective of reducing pedestrian and bicyclist fatalities in the United States, while also increasing accessibility. The updated strategic plan is (1) data driven, taking advantage of existing national resources and databases on multimodal safety trends; (2) anchored in the state of the practice of vast national knowledge on multimodal safety, design, and policy research; and (3) focused on directly implementable countermeasures and strategies.

Office of Safety R&D

The Office of Safety R&D's primary activities reduce injuries and fatalities by better understanding the contributing factors and causes of pedestrian and bicyclist serious injuries and fatalities, identifying and evaluating potential safety improvement measures, fostering public awareness of pedestrian and bicycle safety matters, and providing resources for use at the national, State, and local levels. The Office of Safety R&D is currently undertaking several pedestrian and bicyclist safety-focused research projects.

The Safety Study on Pedestrian Crossing Warning MUTCD W11-2 Sign with Embedded Light Emitting Diodes (LEDs)



The speed of right-turning vehicles can affect pedestrians crossing at an intersection, including whether they start to cross and how quickly they cross.
© Texas A&M Transportation Institute.

looks at a device being used that has LEDs embedded into the border of a crossing sign. The purpose of the study is to investigate the performance of pedestrian or school crossing warning signs that have embedded LEDs that are activated by the pedestrian (not flashing 24/7). The project will determine the effectiveness of the embedded LEDs in terms of whether drivers are appropriately yielding to pedestrians crossing the street.

For the FHWA research project Development of Pedestrian Intersection Crash Modification Factor (CMF), the research team has been tasked with analyzing the relationships between right-turn operations and pedestrian-vehicle crashes at signalized intersections. The team aims to develop a CMF for signalized intersection corner radius and to investigate how turning speeds vary as a function of the design at the intersection corner. The crash analysis is currently ongoing. The final selected model from the speed study can be used to predict the average and 85th percentile turning speeds for a given corner radius. The anticipated CMF can be used to consider the effects of signalized intersection corner radius on crashes.

FHWA recently started a project entitled Evaluation of Aesthetically Treated Crosswalks, which will use a series of closed-course studies to investigate behavior associated with aesthetic treatments of crosswalks. Crosswalk pavement markings provide guidance for pedestrians crossing streets by defining and delineating the path. In recent years, some State and local jurisdictions have added color, patterns, and artwork to crossings within the space between crosswalk markings. The objective of the study is to determine if and how the aesthetically treated crosswalks impact road users' recognition of and behavior at the crosswalk. The outcomes of this project can help FHWA continue to refine the standards and guidance on the design and use of crosswalk markings.

Finally, the study Investigating How Multimodal Environments Affect Multitasking Driving Behaviors will examine multitasking behaviors when drivers are in environments that include large numbers of pedestrians and cyclists. Multitasking behavior refers to any secondary activity not related to the primary driving task, such as engagement on mobile devices, eating, drinking, and talking to passengers. Naturalistic driving data are critical to achieve the objectives of this study, as they offer detailed and objective information about the type and frequency of driver distracting behaviors in everyday driving situations. They also provide a broader context of contributing factors (environment, weather, traffic, season) given a driver's sociodemographic characteristics and vehicle information (type, speed, etc.).

"The Office of Safety R&D is supporting the USDOT's and FHWA's first strategic objective of safety and reducing transportation-related fatalities and serious injuries, particularly for pedestrians," says Brian Cronin, director of the Office of Safety R&D and the Office of Operations R&D. "As one can see from the projects included here, our work focuses on studying countermeasures, road geometries, [and] traffic control devices, as well as evaluating behavior. We are adding technology to our Smart Intersection [at the Turner-Fairbank Highway Research Center], expanding our simulator capabilities, and developing new virtual reality research tools. Feedback received from the USDOT Summit on Pedestrian Safety and the update of the FHWA Bicycle and Pedestrian Strategic Plan will guide the direction of our future pedestrian safety research."

Office of Human Environment

FHWA's Office of Human Environment, part of the Office of Planning, Environment, and Realty, promotes safe, comfortable, and convenient walking and bicycling for people of all ages and abilities. The office supports pedestrian and bicycle transportation through planning, programmatic support, funding, policy guidance, program management, and resource development. In partnership with NHTSA, the Office of Human Environment supports the Pedestrian and Bicycle Information Center, which develops and disseminates resources vital to advancing mobility, access, equity, and safety. Through its website (*www.pedbikeinfo.org*) and monthly newsletters, the center provides timely and relevant pedestrian and bicycle safety research for practitioners.

FHWA's Multimodal Network Connectivity Pilot grant program supported eight communities in their efforts to define and analyze where and why people walk and bike on their transportation networks. Multimodal network analyses like these can assist safety practitioners in predicting where pedestrian- and bicyclist-involved crashes may occur.

The East Central Florida Regional Planning Council and MetroPlan Orlando used this grant to create the Land Overlaid on Transportation Information System (LOTIS), which combines land-use and transportation attribute data into a geodatabase that can be used for a variety of purposes, including safe system analysis. Using the system, the agencies were able to analyze the entire regional transportation network and create a safety score rating for every road segment that estimates pedestrian and bicycle crash risk. The public can browse the system's analysis products at *www.ecfrpc.org/lotis*, and the Office of Human Environment expects to post a summary report on the Multimodal Network Connectivity Pilot grant program in early 2021.

In response to a stated need from practitioners for quick, practice-ready research in pedestrian and bicycle transportation, the Office of Human Environment established the Fostering Innovation in Pedestrian and Bicycle Transportation pooled fund study in 2017. With participation from 14 State department of transportation partners and other FHWA offices, this pooled fund has conducted research into green pavement markings for bicyclists, crosswalk marking designs, and curb extensions for pedestrians.

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A Coordinated Approach

Although FHWA conducts many activities to address pedestrian safety and mobility, a coordinated approach across FHWA, NHTSA, and the Office of the Secretary of Transportation was necessary to successfully plan and launch the USDOT Summit on Pedestrian Safety held in July 2020. The virtual summit discussed issues around pedestrian safety and the initiatives and actions that can improve the safety of pedestrians. The webinars included remarks from former U.S. Secretary of Transportation Elaine L. Chao, former FHWA Administrator Nicole R. Nason, NHTSA Deputy Administrator James C. Owens, and speakers from transportation safety organizations.

In advance of the webinars, coordinators developed a draft list of current and planned USDOT actions to enhance pedestrian safety and shared it with participants. The list identified what the Office of the Secretary of Transportation, FHWA, NHTSA, and other USDOT modes intended to accomplish in the next 2 years. The actions focused on:

- Developing or updating resources, tools, and plans
- Implementing new and revised campaigns, programs, and initiatives
- Creating or revising curricula
- Researching better ways to improve pedestrian safety

Participants provided feedback solicited through interactive polling questions, public chat pods, the website, and email. A review of these comments revealed several important themes: speed, roadway design, technology, and funding.

Speed: Do a better job of setting speed limits, design roadways to encourage slower speeds, approve laws and regulations including the use of speed cameras, and conduct more education on the dangers of speeding to change the cultural mindset that does not view speeding as a serious problem.

Roadway Design: Support pedestrian safety through traffic calming, establish "no car" or slow zones, conduct pedestrian safety audits, and implement complete streets policies.

Technology: Support technology and new vehicle design—including connected and autonomous vehicles—that enable drivers to see pedestrians sooner and engage emergency braking systems when necessary.

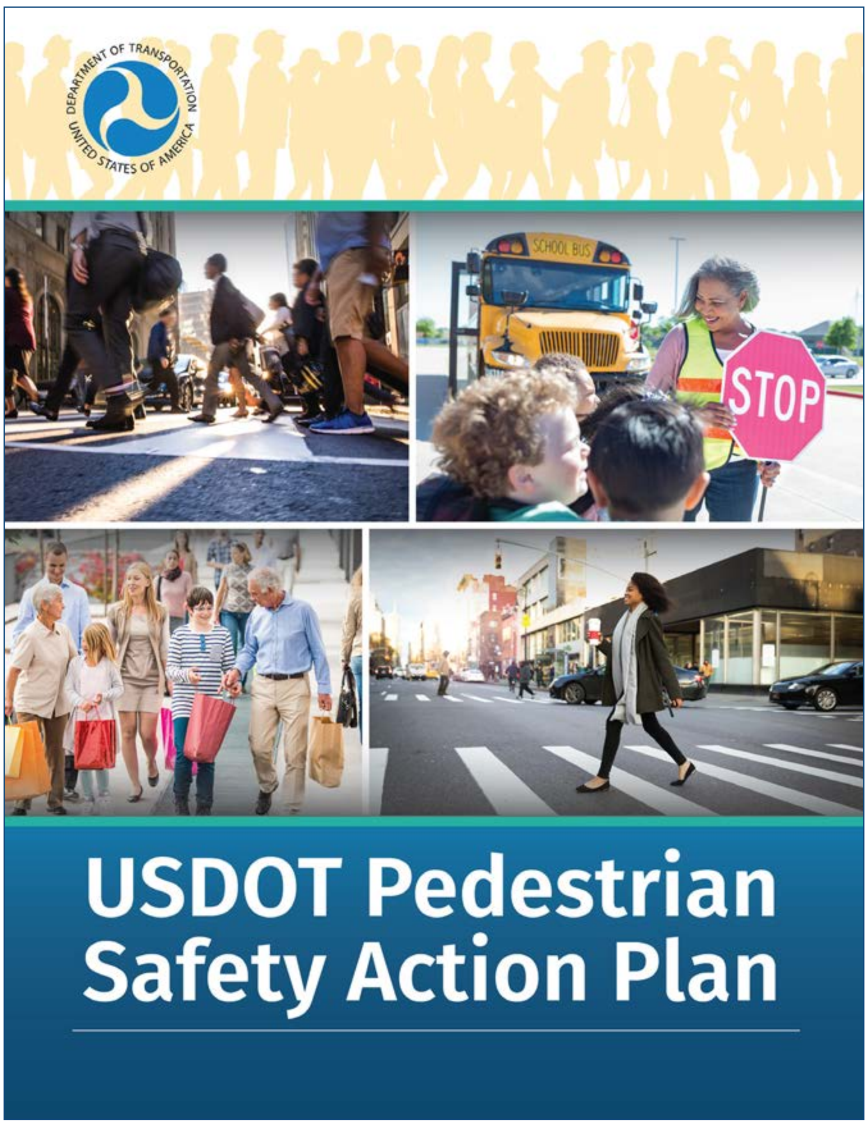
Funding: Address the lack of funding that prevents State and local governments from making needed pedestrian safety improvements.

The collaborative team is gathering and responding to input aimed to ensure that the *USDOT Pedestrian Safety Action Plan* is as comprehensive as possible. FHWA, NHTSA, and the other USDOT agency partners will monitor plan progress to guarantee that pedestrian safety remains at the forefront of public attention. The *USDOT Pedestrian Safety Action Plan* includes actions that will be completed in the near term and those that will be completed in December 2021 and beyond. The plan is available at *https://highways.dot.gov/sites/fhwa.dot.gov/files/2020-11/FHWA_PedSafety_ActionPlan_Nov2020.pdf*.

Setting a Course for the Future

Although pedestrian crashes, fatalities, and injuries remain a worrisome issue, it is encouraging to see some downward movement in the latest numbers. FHWA and other USDOT modal agencies remain committed to increasing pedestrian safety and moving those numbers downward. Although FHWA offers many projects, activities, and research planned and ongoing, the *USDOT Pedestrian Safety Action Plan* and FHWA's updated Strategic Plan will help set a definite course for the future.

"Our shared goal is to get to zero deaths," says Cheryl Walker, FHWA's Associate Administrator for Safety. "We commit to working with all of you to promote safe, comfortable, convenient walking for people of all ages and all abilities."



The *USDOT Pedestrian Safety Action Plan* includes actions that will be completed in the near term and those that will be completed in December 2021 and beyond.

Source: FHWA.

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ANN DO has been the program manager for the FHWA Pedestrian and Bicycle Safety Research program in the Office of Safety R&D since 2001. She specializes in research related to safety effectiveness evaluations, pedestrians, bicyclists, human factors engineering, and geometric design. She received a B.S. in civil engineering from the Virginia Tech Transportation Institute.

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DARREN BUCK is the program coordinator for the Pedestrian and Bicycle Program in FHWA's Office of Human Environment and oversees a variety of projects to research and promote safe, comfortable, and complete networks for bicycle and pedestrian travel. He is a graduate of Virginia Tech's Urban and Regional Planning program, and has an M.B.A. from the University of Maryland.

MICHAEL S. GRIFFITH is the director of FHWA's Office of Safety Technologies. He provides national leadership for safety technologies and countermeasures, policy initiatives, and effective safety investments. He holds an M.S. in transportation engineering from the University of Maryland, an M.A. in statistics from the State University of New York at Buffalo, and a B.A. in business management from Ithaca College.

For more information, visit *https://safety.fhwa.dot.gov/ped_bike* or contact *tamara.redmon@dot.gov*.

LOOKING TO THE SKY FOR GEOTECHNICAL DATA

States are using data from unmanned aerial systems to help predict geological threats, prioritize mitigation efforts, and aid recovery after an event occurs—with reduced costs and improved safety.

by **DERRICK DASENBROCK, JAMES GRAY, BEN RIVERS, TY ORTIZ, JODY KUHNE,** and **KRYSTLE PELHAM**

Unmanned aerial systems (UAS) can provide geotechnical data to transportation agencies while increasing safety and efficiency. These systems can obtain important information, such as rock joint condition and orientation, in locations with difficult access.

© University of Vermont Spatial Analysis Lab.

Transportation projects use unmanned aerial systems (UAS)—often referred to as drones—for many purposes, such as aerial photography, reconnaissance, surveying, structural inspection, and monitoring for documentation, safety, and security. The benefits of using UAS include improved access, better quality, increased safety, greater speed, and improved efficiency.

Although most geotechnical information lies below the ground surface, UAS can evaluate landslides, rockfall, embankment distress, settlement, sinkholes, and similar conditions where measurements associated with visible ground features and ground deformation provide useful information about the subsurface. UAS can also detect the rate of change of these features—which can offer insights on causality, such as seasonal or weather influences, like rainfall events.

UAS are most productive in dangerous or hard-to-access sites, or locations where an aerial big picture bird's-eye—or perhaps 'drone's-eye'—view is useful, or critical, to a complete understanding of a site. Aerial views are often beneficial because of the large scale of some distress features associated with landslides and rockfalls. For geotechnical purposes, high-resolution photos, three-dimensional (3D) point measurements from airborne laser scanning (commonly LiDAR, light detecting and ranging), or structure-from-motion image processing and associated topographic change detection are powerful tools to characterize sites, assess defining geologic features and geohazard threats, and measure movement over time.

The Impact of Rock-Slope Failures and Rockfalls

The American West is known for its rugged geography and impressive mountainous terrain. Whether driving on I–70 near Idaho Springs, CO; traveling on the Seward Highway between Anchorage and the Kenai Peninsula in Alaska; or approaching the Knapps Hill Tunnel on U.S. 97A in Washington State, drivers may encounter an extensive delay or road closure due to a rockfall event. These events are not limited to the West. Many examples of soil and rock slope failures also come from the eastern United States, from the Blue Ridge Mountains in North Carolina to the White Mountains of New Hampshire, or even mid-continent areas along rivers and lakeshores, such as in northern Minnesota. While geologists and engineers strive to design safe highway corridors, rockfall events remain a regular occurrence from of a variety of causes. Natural weathering, freeze-thaw cycles, vegetation, earthquakes, rainfall, and other conditions can lead to rockslides and rockfall.

Rockfall events often result in significant impact to the traveling public. Aside from the obvious safety concerns posed by large rocks falling near or on vehicles, drivers avoiding these rocks or maneuvering to reroute can create additional hazards. Roadway closures to prevent crashes and ensure motorist safety, which often occur with little or no advance warning, can result in significant inconvenience from initial travel delay and lengthy detour routes. Large-scale rock-slope failures can even disrupt routes for months and impact local and regional economies, as described in a 2010 report, *Economic Impact of Rockslides in Tennessee and North Carolina*, prepared for the Appalachian Regional Commission.

Rockfalls can be controlled by a variety of proactive measures that include rock scaling, trim-blasting, mechanical stabilization, and rockfall catchment systems. These are

A rockfall event at the southern portal of the Silver Creek Cliff Tunnel on Minnesota Highway 61 in November 2018 filled the catchment area between the rock face and the protective barrier. UAS can provide safer inspection of sites with recent failures, particularly when site safety is further reduced by snow and ice cover.

Minnesota Highway 61 at Mt. Josephine is the site of two rock cuts where rockfall reaches the travel lanes. The Minnesota Department of Transportation completed the initial surveying with a total station–ground-based survey equipment–followed later with a terrestrial LiDAR survey and point cloud photogrammetry using a UAS.

© Minnesota Department of Transportation.

often effective strategies to reduce the risk to the traveling public. Some sites use multiple control techniques. Proactively preventing all possible rockfall events is impractical, but tools are available to help prioritize mitigation and aid recovery after an event occurs.

The success of the pre-event risk assessment or post-event mitigation strategies is based on an understanding of failure mechanisms, geometry, and the condition of the materials. While the strength of intact rock is an important characteristic, the discontinuities within the rock mass structure—such as the fissures, fractures, joints, faults, and bedding planes, and their condition—usually control how failures occur. These features often follow a geometric pattern locally and sometimes over large areas such as complex joint sets and systems.

Obtaining quality rock slope information can be a risky endeavor involving putting people on potentially unstable terrain to map out geometric features and characteristics of rock formations. Today, transportation agencies are using UAS to conduct these surveys more safely and more efficiently. The digital information acquired by UAS can be quickly processed and deployed to help expedite project delivery.

For example, the Colorado Department of Transportation (CDOT) created a digital model of a rock slope using UAS data and quickly designed a trim-blast after a failure closed I–70 near Dumont, CO, in November 2019. Representatives from CDOT and its contractor viewed the model in a video-conferencing meeting to collaboratively identify and delineate areas of the rock slope for removal. CDOT then shared the model with the blasting company to use for the blast design.

Return on Investment

Many State departments of transportation are investing in geohazard mapping and management programs, as well as the tools to provide the input data for processing, review, modeling, and decisionmaking. UAS is a new option in the geotechnical toolkit that is proving highly effective for improving the quality of information, increasing safety, and reducing project cost, risk, and effort. With better understanding and active geohazard management to anticipate events and proactively plan activities, transportation agencies can efficiently apply rock scaling and removal or other strategies, plan road closures and detours, and inform the public of potential impacts with advance notice.

Technology of various forms, including UAS, is making geotechnical and geohazard asset management easier, safer, faster, and more economical. A short UAS flight in the field can provide data more comprehensively than would have been previously provided by a team of two to three qualified geologists or geo-engineers hiking in an area and manually mapping for several days. UAS can be outfitted with several types of imaging sensors for high-quality photos, structure-from-motion 3D point measurements, and airborne laser scanning.

Topographic change detection, which can be performed more frequently and on a smaller scale with UAS, is a transformative area of development. This process involves comparing two or more temporal datasets. Current applications include larger landform and land use changes (such as open pit mining), mapping changes in snow cover and glaciers, and avalanche detection and mapping. There is a significant return on investment for geologists, geo-engineers, agencies, contractors, the traveling public, and taxpayers.

CDOT is using UAS to collect baseline images after most rockslides. At small sites, the cost of aerial data collection from UAS ranges from 10 percent to 20 percent of the cost of using a helicopter for similar data, depending on location. That cost flips when attempting to collect corridor scans: the time to collect images of a corridor (anywhere from 5 to 10 miles [8 to 16 kilometers] of highway slopes) results in a cost about 200 percent to 500 percent of the cost of collecting images using a helicopter. However, in CDOT's experience, the accuracy of GPS data in images taken from a helicopter has been a concern, and the quality of data is appreciably better from UAS in both image quality and in the ability to process the images.

While CDOT does not have good cost data that show the value of the better quality of the drone image compared to the photographic images from a helicopter, the agency

An aerial view of a rock slope, and an adjacent highway and rail line, as seen from a UAS used on a New Hampshire Department of Transportation research project examining how UAS systems can increase safety and decrease costs of transportation projects.

© University of Vermont Spatial Analysis Lab.

recognizes that the models are much better with UAS-collected images. For CDOT, this accuracy has made UAS worth the additional cost when also considering the value of the model quality—a model created from helicopter-collected images may not provide the opportunity to see change detection at a desired precision for analysis.

Geotechnical UAS Operations

State DOTs generally have established an organizational structure to facilitate safe and efficient UAS operations. Like other UAS operators in both the public and private sectors, geotechnical UAS users must adhere to statutory and regulatory requirements. Application limitations include flight time, location, weather (high winds or inclement conditions), stray currents, and magnetic or radio frequency interference. There could also be poor global positional control, depending on terrain, which would require manual flight by the UAS operator.

A key consideration in the specific use case of rock slope assessment, given the steep and highly variable terrain, is that UAS, including flight planning software, needs to have terrain-following capabilities. In order to have high-quality data from LiDAR and photogrammetry, the ground sampling distance to the sensor must be held constant. Some UAS software can only enable flight at a fixed elevation, rather than at a fixed distance to ground, which is critically important not just for data collection but for safety of UAS in environments where the terrain can change rapidly.

Data can be captured manually or at predetermined intervals. Images taken by UAS are transmitted back to the remote controller, which is typically connected to a mobile data collection device for live image processing. Once the images have been downloaded from the UAS, an extensive array of software is available to process the data for different purposes, including the following:

Photogrammetry, digital aerial photography, and structure from motion—Measurements from UAS photographs combined with correct GPS coordinates produce extremely accurate mapping. The flight images obtained from the UAS overlap, and algorithms within the image processing software can identify related features in each image that enables the images to be stitched together. Dense point clouds can be extracted from digital aerial images, and the density of the data can be similar to airborne laser scanning systems.

Digital terrain modeling—Computer algorithms can predict terrain while ignoring vegetation; digital elevation modeling operates similarly but includes plant life. Both types of modeling enable accurate contour mapping of features.

Airborne laser scanning and 3D modeling—Points are processed using computer software to form a lifelike image composed of a 3D reality mesh model. Analysts can rotate the images produced by the software to provide improved site understanding, to help visualize potential issues, and to identify surface anomalies in the context of the surrounding elements. The 3D models differ from photos in that they are constructed of 3D information that can be employed as a framework to show relationships with other spatial data.

The high-quality digital photos obtained from UAS, even without the benefits of processing, are useful to observe sites from otherwise inaccessible vantage points. For large events, UAS observations often offer a more complete site assessment, providing a larger field of view than is typically available on the ground. This is particularly advantageous when capturing the size and severity of the problem is important.

Site overview imagery is often invaluable for showing nontechnical observers the scope of a landslide, like this one in North Carolina, or rockfall event beyond simple cleanup of the travel lanes.

© North Carolina Department of Transportation.

The University of Vermont Spatial Analysis Lab produced this 3D point cloud from rock slope inspection data for the New Hampshire Department of Transportation. The work was done as part of the study on UAS applications to reduce cost and increase safety for traffic operations at Crawford Notch State Park.

Managing Geohazards in Colorado

CDOT's Geohazard Program has used some form of aerial data collection since the 1990s. At that time, photographic images mainly documented construction activities and reviewed oblique, aerial images of steep slopes. Recently, the program has been collecting baseline images, in the form of structure-from-motion and LiDAR point clouds, of geohazard corridors and after geohazard events.

"With these advances in aerial data collection and processing over the past several years, the use of UAS has become part of the workflow for several of our programs at CDOT," says Stephen Harelson, P.E., chief engineer at CDOT.

Over time, as additional data are collected, change detection will direct investigation to specific slopes within in a corridor. In combination with other information such as UAS rockfall hazard rating system, precipitation, temperature data, and change detection maps created from surveys, the agency's goal is to establish the likelihood of an event and manage risk. Based on an informed probability, CDOT can direct detailed investigations to those areas of a slope that appear most susceptible to failure based on data and subject matter expert observations and review. It is important to note that even the most informed tools and techniques still only provide predictions of future outcomes.

Geotechnical Applications in North Carolina

For emergency landslide roadway closures, the North Carolina Department of Transportation (NCDOT) Geotechnical Engineering Unit supplies a working plan within 24 hours, typically with biddable items provided within 72 hours. UAS has facilitated the entire process by enhancing four critical general project items:

- Fast aerial overview to provide NCDOT management and the public with an idea of the scale and potential impact of the problem.
- Supplemental information from the field review to develop the immediate mitigation approach, scope, specialty geotechnical repair items, quantities, and mitigation limits (for potential right-of-way and permitting requests and requirements). This includes information necessary to assess slope stability and the potential for partial highway reopening prior to project completion.
- Periodic overview of progress during mitigation to inform management, the public, and project inspectors without requiring hazardous slope access.
- Initial and final orthophoto, topographic, and point cloud projections, requiring limited hazardous surveying and estimating, for final project pay quantities.

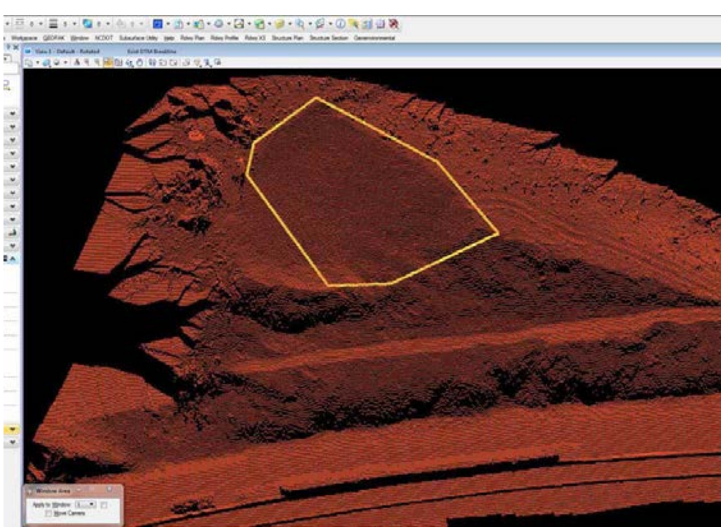
NCDOT used UAS on a project along I–40 in February 2019. A simple initial overview provided general quantities, mitigation boundaries, and specialty items anticipated from the contractor. The UAS images helped observe and document project progress and assisted in determining when conditions were at the point where rockfall barriers could be placed and detour travel lanes opened.

"Aside from the established and emerging technical applications of UAS data," says D. Clayton Elliott, a geological engineer in NCDOT's Western Regional Office, "the ability to provide an immediate oblique view of many geotechnical projects for concept, safety, and construction is now an expected part of any project."

New Applications Evaluated in New Hampshire

The New Hampshire Department of Transportation (NHDOT) recognized that the use of UAS had the potential to reduce costs and increase safety for a variety of transportation operations. In 2017, NHDOT, in partnership with the University of Vermont's UAS team, began a research project focused on evaluating UAS technology for a broad range of case studies including rock slope inspection. One case study focused on the inspection of a rock slope near Crawford Notch State Park in July 2017. The University of Vermont's UAS team conducted three flights, collecting 310 photos during a total flight time of just over half an hour. The effort had two goals: (1) create a high-resolution georeferenced point cloud of the rock slope suitable for 3D modeling to analyze the rock structure, and (2) capture high-resolution inspection photos of the rock slope to provide multiple viewpoints of the rock face.

The team created a 3D model using the 310 images and digital photogrammetric techniques and generated a seamless orthorectified image mosaic. The processing for this project took approximately 70 minutes to complete. The final report, *The Integration of Unmanned Aircraft Systems to Increase Safety and Decrease Costs of Transportation Related Projects and Related Tasks* (FHWA-NH-RD-26962J), provided several findings related to inspection and safety. First, the



Derivative products from UAS orthoimagery (small-scale photogrammetry) enable transportation agencies to assess earthwork pay quantities. The outlined area illustrates the location where slope mesh and retaining anchors will be installed. NCDOT and its contractor agreed on this method of measurement for payment, decreasing the work required for onsite inspectors.

UAS provided a view of the rock slope that an inspector would be unable to view from the ground. Second, working on the ground near rock slopes is not risk-free because of potential rock fall and frequent roadway traffic. Using UAS generally keeps personnel safer from potentially dangerous rock slope site conditions. Third, the detailed 3D rock slope models provided measurements in locations that are unreachable by manual measurements, or only accessible using potentially dangerous rope-access methods.

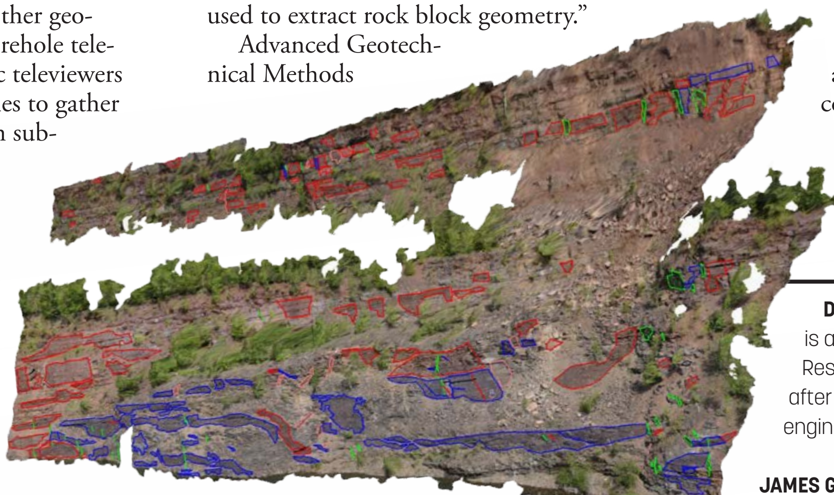
Integrating Surface and Subsurface Measurements

Surface mapping and imagery from UAS can add even greater project value when used in combination with other geotechnical tools, such as a borehole televiewer. Optical and acoustic televiewers can be employed in boreholes to gather high-quality information on subsurface stratigraphy as well as rock joint and fracture orientation.

The Minnesota Department of Transportation (MnDOT) relocated a portion of U.S. 53 between Eveleth and Virginia, MN. Future iron ore mining adjacent to the alignment has the potential to create excavated rock slopes up to 500 feet (150 meters) high, in addition to existing slopes, requiring characterization of rock discontinuities. MnDOT used two innovative methods to collect the information: down-the-hole televiewer logging (both optical and acoustic) and photogrammetry using images acquired via UAS.

Once the team completed the field work, they began the joint mapping task. A private consulting group, one of MnDOT's project partners, first constructed the models from photographs and geo-referenced them using a structure-from-motion application and contact-free measurement of geological/geotechnical parameters. The 3D images provided comprehensive documentation by reconstructing the geometry of the rock walls, with measurement of geometric and geologic features represented as points, distances, areas, and orientations. The optical and acoustic logging was most useful for determining the spacing between recurring joint-sets (persistence), and the photogrammetry was only helpful for estimating persistence. During construction excavation, the persistence was shown to be greater than measured using photogrammetry because the full extent of joints was obscured by talus and vegetation.

"[We have] found UAS imagery, plus the resulting point clouds and meshes, to be invaluable in characterizing inaccessible rock exposures," says Dr. Lee Petersen, P.E., a principal engineer with one of MnDOT's partners. "We typically capture still photographs to support photogrammetry (to make the point clouds and meshes), and videos to better understand rock outcrop geometry and discontinuities. The point clouds are used to extract discontinuity location and orientation, and meshes are used to extract rock block geometry."



An example image of mapped rock joints from a UAS photogrammetry survey along a rock slope at a proposed bridge location on the U.S. 53 relocation project in Virginia, MN.

Advanced Geotechnical Methods in Exploration (A-GaME), an initiative of round 5 of the Federal Highway Administration's Every Day Counts (EDC) initiative, listed televiewers and UAS as highlighted technologies (*www.fhwa.dot.gov/innovation/everydaycounts/edc_5/geotech_methods.cfm*).

Integrating UAS into Asset and Management Programs

UAS provide another tool in the geotechnical toolbox for site characterization. Benefits include fast response to emergency events, decreased data acquisition time, reduced cost, greater operational efficiency, improved quality, and significantly improved safety at hazardous or unstable sites. Transportation agencies' use of UAS has increased significantly in the past few years, and many State DOTs have created new programs related to UAS applications. The photos, videos, and 3D measurements obtained from UAS are already improving standards of practice for geohazard visualization, change detection, risk assessment, informed decisionmaking, and hazard/asset management.

UAS use increases productivity during data collection and enables more efficient processes and more rapid detection of areas of concern. These advantages, combined with generating high-quality end products, are significant benefits considering the additional value that total data collection costs may decrease due to reductions in labor, time, and other expenses.

UAS technology, coupled with geotechnical project implementation, provides an opportunity for improved practice merging surface and subsurface data for a significant return on investment and improved risk management—leading to reduced costs, improved safety, and, perhaps most noticeable to the public, fewer traveler delays because of unexpected road closures from geohazards.

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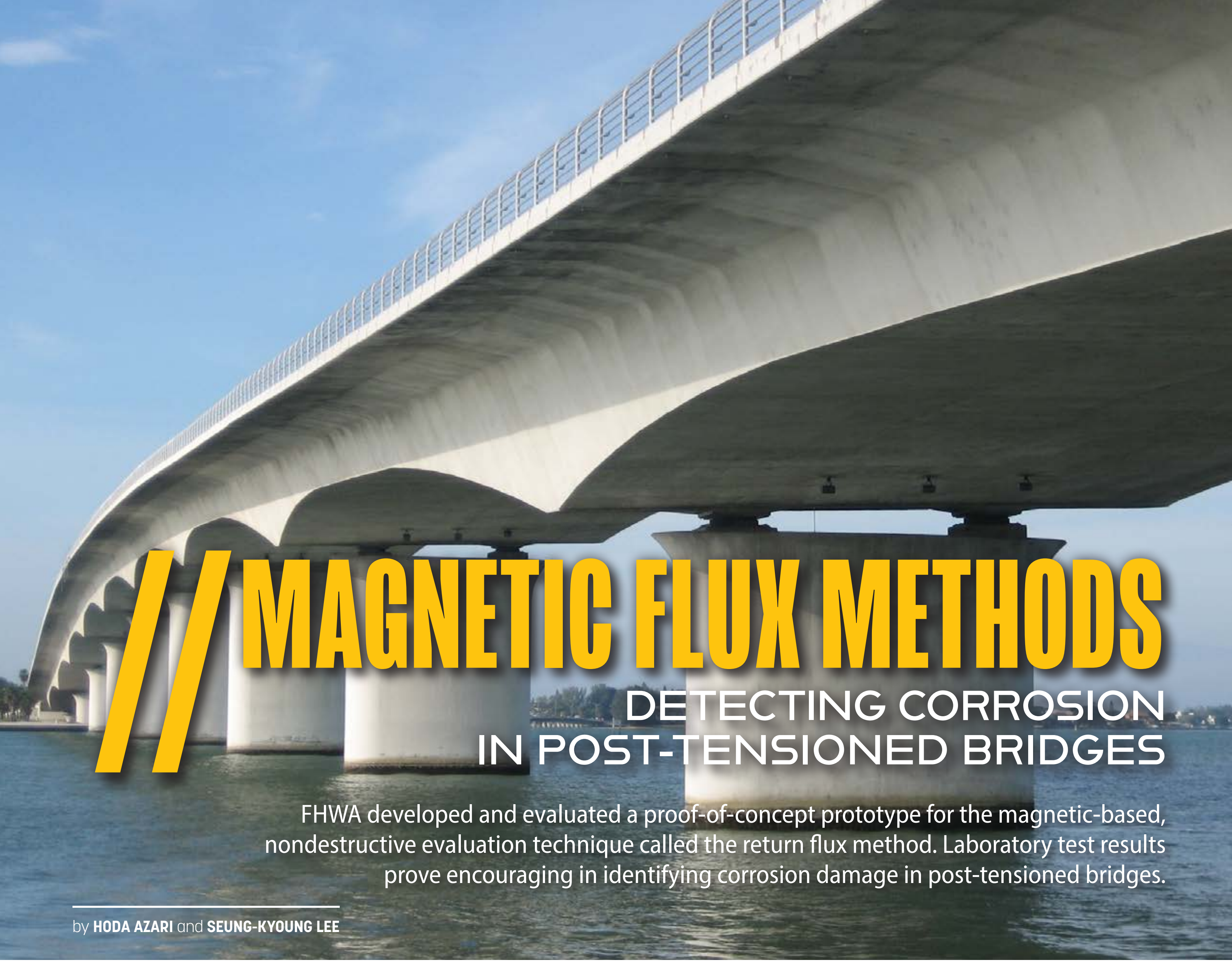
For more information, visit *www.fhwa.dot.gov/innovation/everydaycounts/edc_5/uas.cfm* or *www.fhwa.dot.gov/innovation/everydaycounts/edc_5/geotech_methods.cfm* or contact James Gray at 703–509–3464 or *James.Gray@dot.gov*, or Ben Rivers at 678–613–2807 or *Benjamin.Rivers@dot.gov*.



// MAGNETIC FLUX METHODS

DETECTING CORROSION IN POST-TENSIONED BRIDGES

FHWA developed and evaluated a proof-of-concept prototype for the magnetic-based, nondestructive evaluation technique called the return flux method. Laboratory test results prove encouraging in identifying corrosion damage in post-tensioned bridges.

by **HODA AZARI** and **SEUNG-KYOUNG LEE**

FHWA is exploring a nondestructive evaluation method to identify corrosion in post-tensioned bridges, which are common in the United States. Shown here is the Ringling Causeway Bridge in Sarasota, FL, which needed to have many external post-tensioned tendons replaced.

© Seung-Kyoung Lee.

Post-tensioning in bridge structures offers many benefits. It provides better performance during seismic activity; it reduces or eliminates shrinkage cracking, therefore requiring fewer or no joints; it holds cracks tightly together; and it enables slabs and other structural members to be thinner. Post-tensioning is a constructive technology in modern bridge structures including segmental box girder bridges and cable-stayed bridges. However, the potential for corrosion of the steel strands that provide post-tensioning in prestressed concrete bridges continues to be a concern.

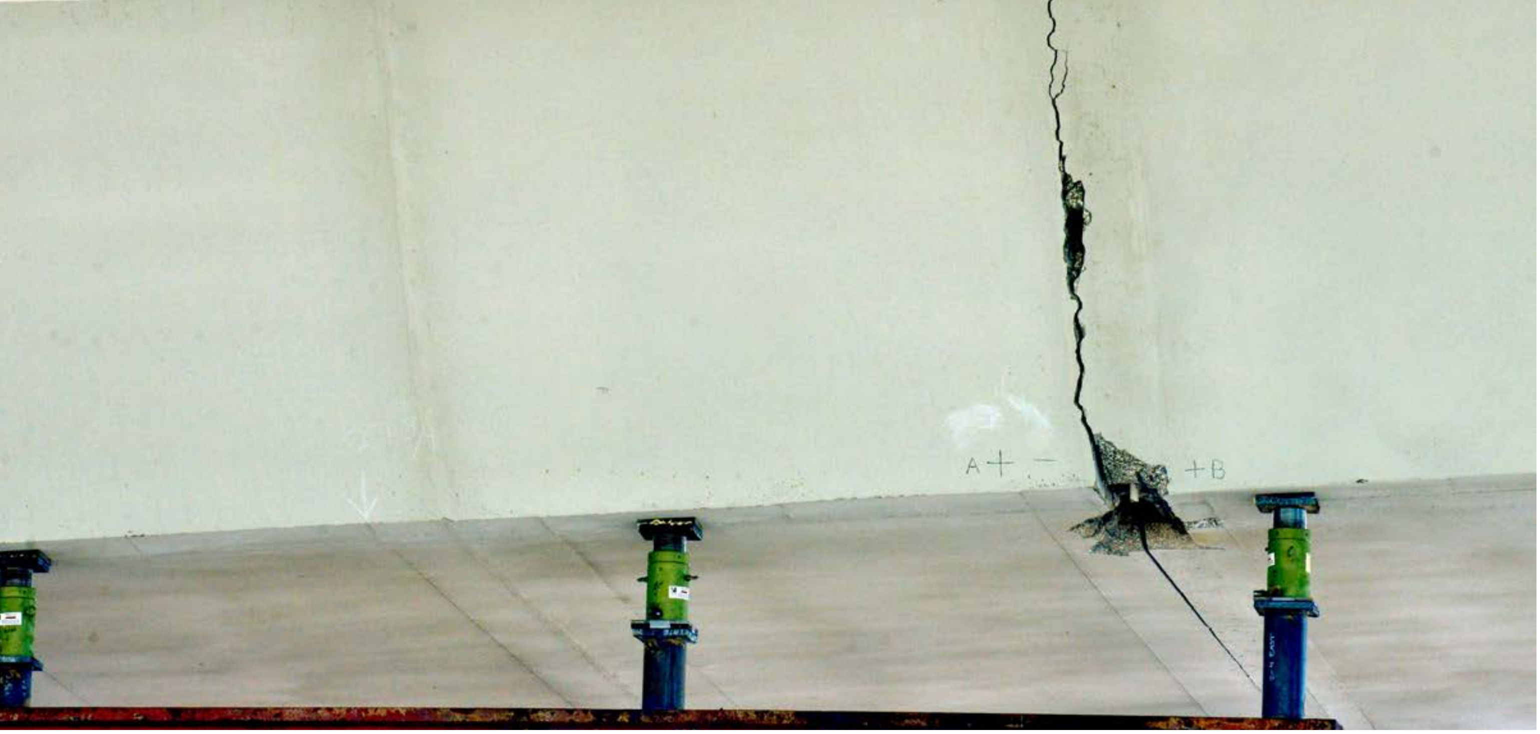
Among nondestructive evaluation (NDE) technologies, magnetic-based methods have evolved to become promising techniques to identify corrosion of metallic members embedded in concrete structures. An 18-month laboratory study conducted at the Federal Highway Administration's NDE Laboratory developed and evaluated a proof-of-concept prototype based on the return flux method.

Progressive Corrosion of Post-Tensioned Tendons

Post-tensioned strands are protected from corrosion by a passive film formed in cementitious grout, which also serves as a physical barrier to water, oxygen, and carbon dioxide. However, post-tensioned tendons have been discovered frequently to contain grout deficiencies such as segregated grout and grout voids that can indicate high-risk areas of corrosion. In other words, corrosion susceptibility of the highly stressed post-tensioned strands in the grouted tendons increases as grout quality surrounding the strands decreases.

Post-tensioned bridges in the United States have experienced tendon failures or serious corrosion problems since 1999. On November 13, 2009, the Indiana Department of Transportation (INDOT) closed the Cline Avenue (SR–912) bridge over the Indiana Harbor Ship Canal after a routine inspection revealed significant corrosion of the steel tensioning cables and rebar within the box girders because of water seeping through cracks in the bridge deck. After determining that the level of corrosion had compromised the bridge's structural integrity beyond repair, INDOT decided to permanently close and eventually demolish the entire bridge to build a new one.

More recently, in June 2020, detailed



In June 2020, an inspection of the temporarily closed Roosevelt Bridge in Florida revealed corrosion and ruptured steel strands. Shown here is the exterior view of the damaged location.

© Julian Leek / Alamy Live News, Alamy.com.

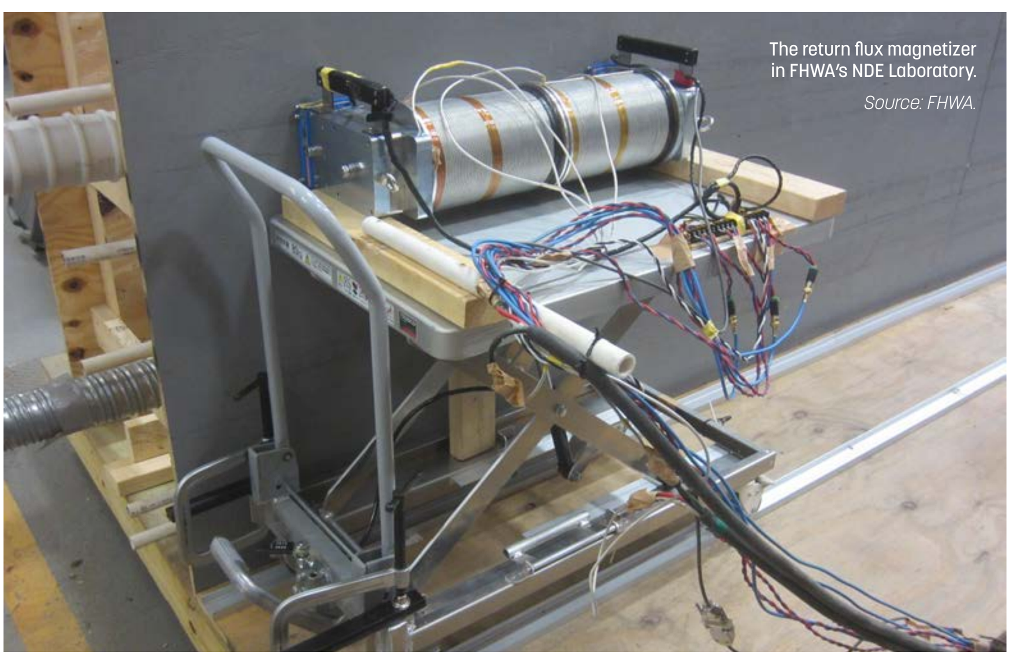
inspections of the temporarily closed Roosevelt Bridge in Stuart, FL, revealed severe corrosion and ruptured steel strands in the southernmost portion of the 23-year-old bridge's southbound span.

Developing an NDE Technique for Internal Post-Tensioned Tendons

While tendon corrosion can occur in both external and internal post-tensioned tendons, even careful monitoring of internal tendons embedded in the concrete may not reveal corrosion problems until it is too late.

"As in-service post-tensioned bridges containing internal tendons get older, the need for reliable ways to assess for this type of structure grows. Effective NDE methods can help," says Joseph Hartmann, the director of FHWA's Office of Bridges and Structures. "In addition, repairing or replacing corroded internal post-tensioned tendons is cumbersome or, in many cases, nearly impossible compared to similar work for external tendons."

To overcome these problems and difficulties in the field, many agencies have employed NDE technologies such as ground penetrating radar, impact-echo, ultrasonic surface waves, and ultrasonic tomography to inspect internal post-tensioned tendons. However, current techniques may be able to detect some types of grout deficiencies but not corrosion of the metal tendon components themselves, and therefore detecting metal corrosions is difficult and inconclusive.



The return flux magnetizer in FHWA's NDE Laboratory.

Source: FHWA.

Return flux technology can detect corrosion of steel strands in the internal post-tensioned tendons. FHWA's NDE Laboratory, in collaboration with a contracted manufacturing company, developed the concept of the return flux system based on the fundamental principle of magnetic main flux: when a ferromagnetic material, such as steel strands, is magnetized close to a saturation level, the magnitude of the magnetic flux going into the material is proportional to its cross-sectional area. If corrosion damage reduces the cross-sectional area, the magnetic flux decreases accordingly. With the technology, the internal tendons embedded in concrete are magnetized using a specially designed yoke-type magnetizer and the system measures return flux via multiple Hall-effect sensors and search coils.

Magnetic main flux is measured after wrapping a magnetizer around an external post-tensioned tendon. In contrast, the return flux method uses a two-yoke-type magnetizer that is placed on the concrete surface directly over an internal post-tensioned tendon. After magnetizing the buried tendon from one yoke to the opposite yoke, researchers can measure the magnetic flux on the return yoke.

Because concrete is essentially a nonmagnetic material with a relative magnetic permeability of unity, it exerts a negligible influence on the magnetic measurements through the gap that can be clear concrete cover in actual post-tensioned structures plus an air gap between the yoke bottom and concrete surface.

The research team conducted an extensive numerical simulation to maximize the effectiveness of the system in terms of the strength of magnetic fields. The final prototype consists of a pair of solenoid coils in series layout between two yokes. The yoke-type solenoid magnetizer was able to exert a strong magnetic field through air gaps and different concrete cover depths.

There is an inherent gap between the pair of yokes and the concrete over the internal tendons, which affects the measurement accuracy by leaking flux through the air. To address this, the researchers elongated the length of the coils to minimize the magnetic flux leaking in the air by increasing resistance in the air between the yokes. The team found that the optimal diameter and length of the solenoid coils are 4.7 inches (11.9 centimeters) and 20.6 inches (52.3 centimeters), respectively.

"Condition assessment of embedded pretensioned strands and post-tensioning tendons in prestressed concrete bridges is one of the high priority bridge performance issues identified by FHWA's Long-Term Bridge Performance Program and its stakeholders—mainly the State DOTs," says Dr. Jean Nehme, the team leader for FHWA's Long-Term Infrastructure Performance Team. "Performance of embedded prestressing strands and post-tensioned tendons will be assessed in detail as part of the program. Therefore, this technology will be helpful in acquiring the data necessary to assess these components."

The design of the mockup became crucial to the system development. The research team considered key features of a typical web of segmental box girders containing internal tendons. They included sufficient concrete cover between a mockup internal tendon and the magnetizer, two types of duct material (metal and plastic), and horizontal and vertical reinforcing bars. The team fabricated two mockup tendons. Each could accommodate up to 19 7-wire strands with different simulated cross-sectional loss and a real anchorage zone composed of wedge plate, bearing plate, transition tube, and spiral confinement reinforcement in a realistic configuration.

Research Outcomes

The team evaluated various test parameters, such as return flux and leaked magnetic flux, using strategically placed search coils and axial and radial Hall-effect sensors. Test results showed that the proof-of-concept prototype successfully detected 15.3 percent or larger section loss introduced in the mockup internal tendons surrounded by vertical rebars at 6-inch (15-centimeter) or wider spacing and clear concrete cover less than 7.4 inches (18.8 centimeters) for metal ducts, and 6.4 inches (16.3 centimeters) for plastic ducts.

"These initial results are promising," says Cheryl Richter, the director of FHWA's Office of Infrastructure Research and Development, "and suggest that the return flux method is viable as the basis for field-deployable NDE systems to detect section loss in post-tensioning strands."

HODA AZARI is the manager of the NDE Research Program and FHWA's NDE Laboratory at the Turner-Fairbank Highway Research Center. She holds a Ph.D. in civil engineering from the University of Texas at El Paso.

SEUNG-KYOUNG (SK) LEE is the founder and president of a private consulting firm. Dr. Lee has been working on corrosion of different types of reinforcing steel and prestressed strands, protective steel coatings, cathodic protection, corrosion monitoring sensors, and non-destructive evaluation of post-tensioned tendons. He is a former chair of the Transportation Research Board's Corrosion Committee and Steel Bridge Coating Subcommittee. He holds a Ph.D. in ocean engineering from Florida Atlantic University.

For more information, contact Hoda Azari at 202–493–3064 or *Hoda.Azari@dot.gov*.

The lab's bridge mockup is composed of post-tensioned tendons and an anchorage zone.
Source: FHWA.

ALONG THE ROAD

The Volpe Center is assisting the National Park Service with an automated shuttle pilot that will provide service in Yellowstone's Canyon Village, located near the scenic Grand Canyon of Yellowstone, shown here.

Source: Volpe Center.

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.

Personnel

'Mayor Pete' Buttigieg Begins New Era as U.S. Secretary of Transportation

On February 3, 2021, Pete Buttigieg was sworn in as the Nation's 19th Secretary of Transportation, ushering in a new era focused on climate change, racial equity, and economic development.

Previously, he served two terms as mayor of South Bend, IN. After graduating from Harvard University and completing his time as a Rhodes Scholar at Oxford University, Buttigieg served for 7 years as an officer in the U.S. Navy Reserve, taking a leave of absence from the mayor's office in 2014 for a deployment to Afghanistan.

Known widely as "Mayor Pete," Buttigieg worked to transform South Bend's future and improve daily life for its residents. During Buttigieg's time as mayor, South Bend's household income grew, poverty fell, and unemployment was cut in half. The city established new resources to extend opportunity and access to technology for all residents, and launched a "Smart Streets" initiative to improve street design. His complete streets strategy helped to fuel small business growth along previously neglected corridors, and attracted hundreds of millions of dollars in private investment in the once-emptying downtown.

His leadership helped spark citywide job growth and facilitated innovative public-private partnerships like Commuters Trust, a benefits program designed to improve the city's transportation experience for workers.

In 2019, he launched his historic campaign for President. Throughout 2020, he campaigned for the election of the Biden-Harris ticket and served on the advisory board for the Presidential transition. In December, he was nominated by President-elect Biden to be Secretary of Transportation. He was confirmed by the Senate on February 2, 2021, becoming the first openly gay person confirmed to serve in a President's Cabinet.

Public Information and Information Exchange

Watch the EDC-6 Virtual Summit On-Demand

In December 2020, more than 2,000 people attended the EDC-6 Virtual Summit to learn about the new innovations featured in the sixth round of the Federal Highway Administration's Every Day Counts program (EDC-6). For anyone who could not attend, the sessions, videos, and print material are available on demand.

Watch team leaders lay out their vision for each EDC-6 innovation, listen to compelling success stories from agencies already using them, explore the virtual exhibit floor to learn about innovations from this and past rounds of EDC, and visit the National State Transportation Innovation Councils (STIC) Network Showcase to learn about more than 200 homegrown innovations developed and deployed across the country.

The agenda for the virtual summit is available at *www.fhwa.dot.gov/innovation/everydaycounts/edc_6/summit.cfm*. To access the summit content, which will be available until December 2021, register at *www.labroots.com/ms/virtual-event/fhwa-everyday-counts-6-virtual-summit*.

For more information, see the "Innovation Corner" on page 3 of this issue of *Public Roads*.

USDOT Releases Update to ITS Architecture Reference and Toolsets

In late 2020, the U.S. Department of Transportation released the Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT) version 9.0, a major update to the Intelligent Transportation Systems (ITS) reference architecture and accompanying toolsets—the Regional Architecture Development for Intelligent Transportation (RAD-IT) and the project-focused Systems Engineering Tool for Intelligent Transportation (SET-IT).

ARC-IT and its tools support development of customized regional and project architectures to meet local needs while enabling safe, secure, and efficient nationally interoperable ITS deployments. Changes include enhanced content to support vehicle automation informed by research results and stakeholder input, including the National Dialogue on Highway Automation, along with expanded ITS services.

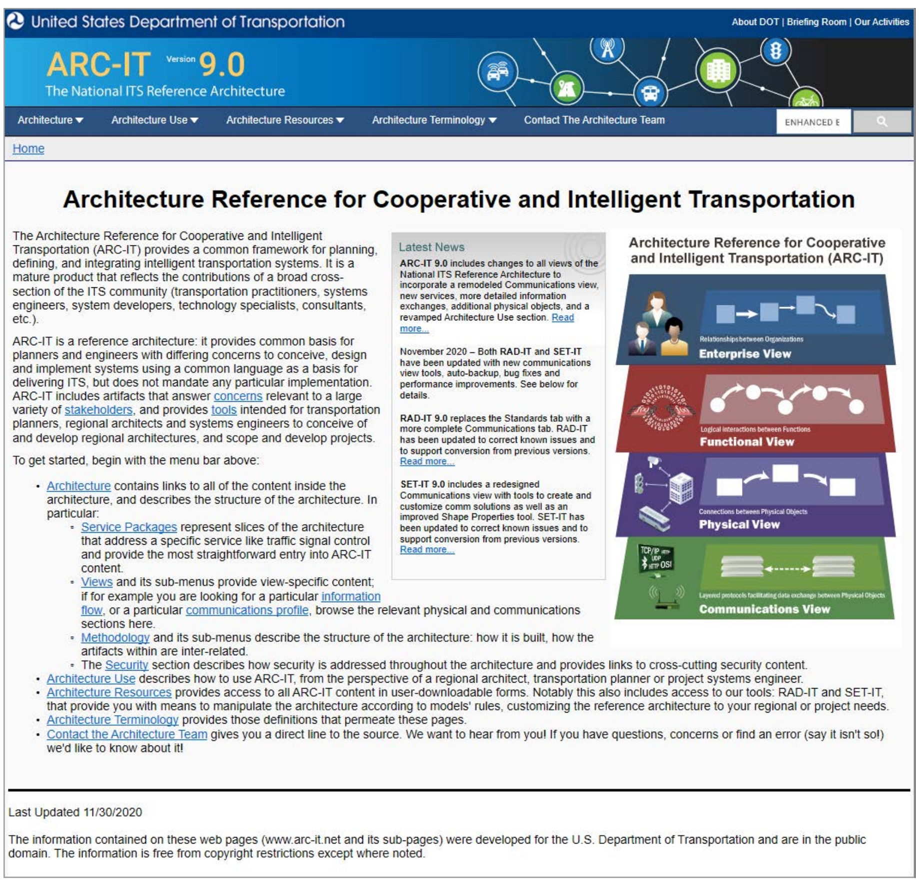
ARC-IT 9.0 expands the Communications Viewpoint with re-imagined diagrams along with greater detail on information exchanges and identification of suitable standards. As ARC-IT now includes services and content contributed by multiple international partners, it now supports geographic-awareness to facilitate use in multiple regions and to enable U.S. use of internationally contributed services.

Version 9.0 adds several new ITS services (for a total of 150 services), along with new physical and functional objects. It also reintroduces "environmental terminators" that describe system boundaries representing the roadway and surrounding physical environment that ITS subsystems might sense or need to accommodate. Users of version 7.1 and earlier might recognize some of these; their purpose now is to enable users to better understand the relationships between the physical environment and the entities that own, operate, and maintain the roadway and vehicles, with specific interests associated with highly automated vehicles.

As with version 8.3, ARC-IT 9.0 is available online at *www.arc-it.net* or via a single download that contains most ARC-IT content that may be installed locally for offline use.

The RAD-IT regional and SET-IT project architecture toolsets have both been upgraded to accommodate ARC-IT 9.0 along with additional standalone features, including the enhanced ability for users to exchange information between the two tools.

For more information, visit *http://local.iteris.com/arc-it/html/whatsnew/whatsnew.html*.



Source: USDOT.

Volpe Center Supports First NPS Automated Shuttle Pilot

In May 2021, the National Park Service (NPS) will host its first automated shuttle pilot in the Nation's first national park, Yellowstone National Park. The pilot will involve the deployment of a low-speed automated shuttle in the Canyon Village area of Yellowstone. The project is using funds provided by the FHWA Technology and Innovation Deployment Program in concert with FHWA's Office of Federal Lands Highway.

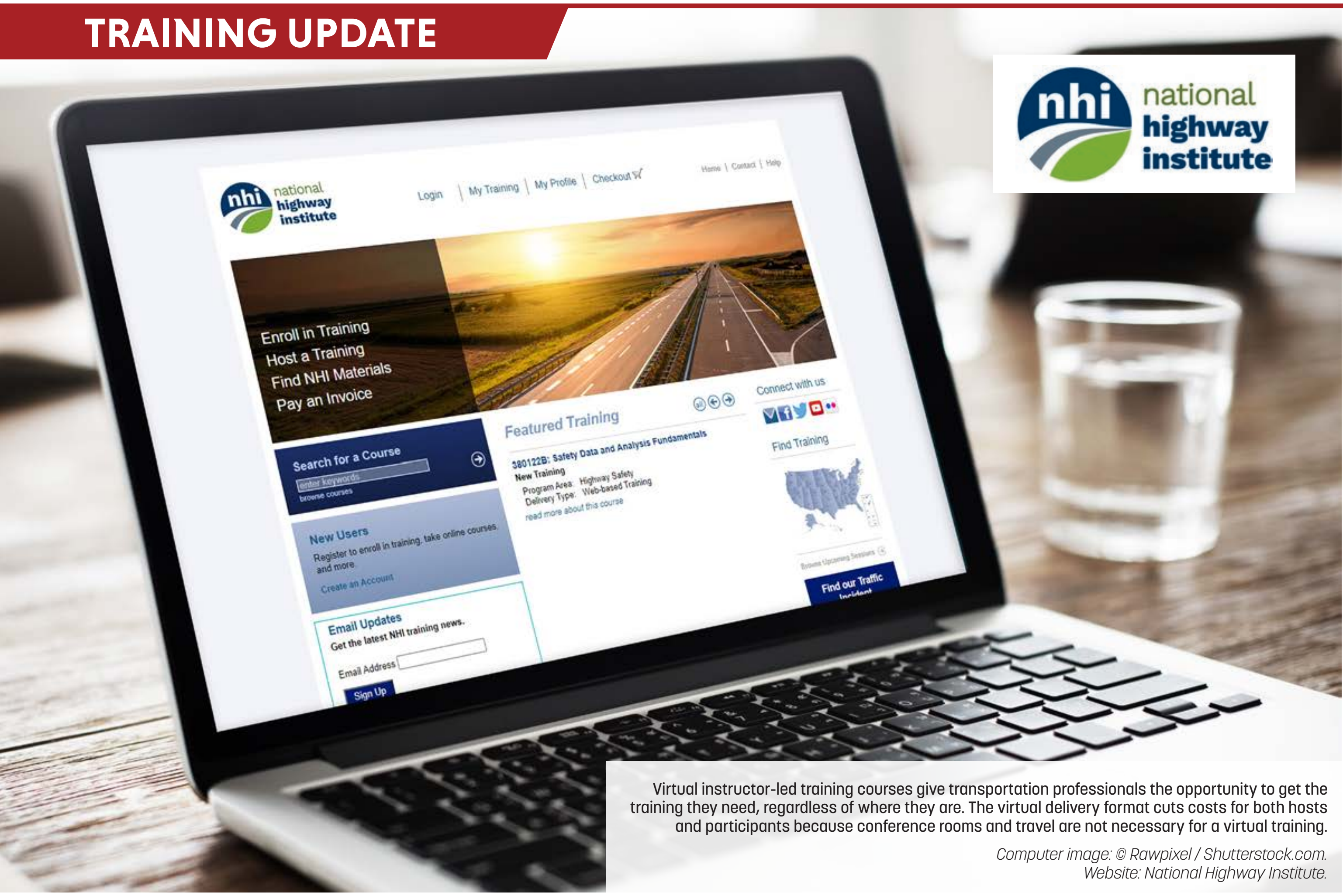
NPS has three primary goals for this pilot. First, to enhance the visitor experience by facilitating new interpretive opportunities and improving mobility assistance. Second, to demonstrate the use of autonomous vehicle (AV) shuttle technologies for public use in novel operating environments, including rural/remote areas and/or recreational settings in mixed traffic, and how those outcomes could be applied to other public lands. Finally, to identify and overcome unforeseen regulatory and organizational barriers of emerging mobility technologies.

To date, most automated shuttle pilots have been held in urban areas, and the remote setting at Yellowstone will provide NPS and AV industry leaders with an opportunity to assess the suitability of these technologies for use in public lands.

USDOT's Volpe National Transportation Systems Center (Volpe Center) supported the NPS pilot through technical assistance, including the development of a sources-sought request to learn more about automated shuttle technologies and a request for quotes that resulted in the selection of a private vendor to conduct the pilot. Volpe staff have also provided technical expertise on automated shuttle technologies to NPS staff.

The Volpe Center will continue to provide technical assistance to NPS as pilot planning continues. Volpe will also carry out an evaluation of the pilot following its completion in fall 2021. This evaluation will involve assessing the performance of the shuttle and its automated technology based on a range of metrics to be collected during the pilot, including shuttle ridership, route performance, battery performance, and interventions from the shuttle's safety operator. By assessing the shuttle's performance in Yellowstone's remote/recreational setting, the evaluation will inform potential use cases for automated shuttle technologies at other NPS and public land sites.

For more information, contact Travis Crayton at *Travis.Crayton@dot.gov*.



Virtual instructor-led training courses give transportation professionals the opportunity to get the training they need, regardless of where they are. The virtual delivery format cuts costs for both hosts and participants because conference rooms and travel are not necessary for a virtual training.

Computer image: © Rawpixel / Shutterstock.com. Website: National Highway Institute.

NHI Expert Instructors: Coming to a Computer Near You!

by **THOMAS HARMAN** and **CHRISTINE KEMKER**

Virtual learning is a valuable tool in the workforce development toolbox. Self-paced, online courses offer learners the opportunity to train on their own schedule. The National Highway Institute's virtual instructor-led training is conducted via web conferences to provide participants with real-time interaction with the instructor. The complexity of transportation disciplines makes having a live instructor instrumental.

Despite the in-person meeting restrictions in 2020, the Nation's transportation industry did not stand still—thus training could not wait for in-person gatherings to be widely accessible again. Last year, NHI converted 30 of its instructor-led training courses to *virtual* instructor-led training (VILT) courses. Now organizations can host a variety of NHI courses virtually, bringing expert instructors to employees for real-time training.

The virtual format offers organizations more flexibility in both hosting and attending training. "The new virtual delivery format allows customers to better target training while reducing costs," says Gay Dugan, a training program manager for NHI. "You can host a course just for your staff, or open public seats so peers from across the region or Nation can attend."

Opening seats up to the public helps defray costs while increasing valuable collaboration among participants. NHI itself is also hosting several training courses as national sessions, with open enrollment so that individuals from across the country can register.

Sparking the Shift

Since the mid-1990s, NHI has pioneered new ways to provide valuable distance learning. From training courses shared on floppy disks and course delivery via satellite transmission to HTML5 web-based courses, NHI has been at the forefront of learner-centric, accessible training. NHI's initiative on distance learning led the Nation, from creating web-based trainings and web-conference trainings first offered in 2003 to blended learning in 2006. Since the early 2000s, online trainings have been in high demand and NHI has collaborated with industry partners and experts to develop a catalog of more than 200 self-paced, web-based trainings for transportation professionals.

While the benefits of self-paced learning are evident, and the increase in professionals taking web-based trainings demonstrates demand, instructor-led trainings have remained a consistent standard for training. Interacting with expert instructors and engaging with peers in the transportation industry supports learning complex topics and enables participants to receive immediate answers to questions.

Meeting the Industry Need

2020 presented a challenging opportunity, as State departments of transportation and other transportation organizations across the country had previously scheduled their employees to get the training they needed to do their jobs through instructor-led trainings. With the cancelation of more than 400 in-person sessions, NHI stepped up to the challenge of providing the needed training virtually.

NHI quickly pivoted and successfully converted its high-priority instructor-led trainings to a virtual format. NHI scheduled 14 sessions of its Instructor Development Course for web-conference trainings in order to rapidly ramp up and prepare instructors from the Federal Highway Administration's Resource Center and NHI to teach in a virtual environment. Concurrently, NHI's training program managers worked with their course designers to prioritize and convert content for a virtual online training.

Stacey Jones, a training program manager at NHI, says of the VILT conversion process, "It was awesome to see how quickly and easily our partners came together when we had to convert face-to-face [trainings] for virtual delivery."

In under 5 months, NHI converted 30 high-demand, instructor-led training courses to a virtual format and continues to work on converting more.

NHI's VILTs continue to provide participants with the right information and tools needed to enhance their skills and support advancement in their respective careers. NHI is an International Association for Continuing Education and Training accredited provider, which means that most of the converted courses still provide continuing education credits upon passing the course. These credits can be converted to professional development hours for license requirements for State or professional organizations.

NHI is offering all VILT courses at a discount through the end of 2021. Visit NHI's website to see what VILTs are available in your discipline and ask your organization to host a session this year.

How to Attend or Host a VILT

Many of these VILT courses are available as national sessions—anyone across the country can register and attend. Virtual trainings can also be "hosted" by any State DOT or transportation agency through the same process as regular instructor-led trainings. NHI can provide the training on FHWA's virtual platform or agencies may use their own virtual platform. NHI provides instructions, course materials, and expert instructors. If an agency would like to open a session up as a regional or national session, NHI will work with the organization and can even help with marketing. Host requests can be submitted directly from the course page—submit a request today!

NHI invites professionals interested in earning continuing education credits or expanding their career skills to visit *www.nhi.fhwa.dot.gov/home.aspx* and browse the complete digital course catalog, which spans 18 transportation program areas.

THOMAS HARMAN is NHI's director.

CHRISTINE KEMKER is a contracted marketing specialist working with NHI.

NHI's VILT Course List

Asset Management
- FHWA-NHI-136002V Financial Planning for Transportation Asset Management
- FHWA-NHI-136106V Introduction to Transportation Asset Management with Workshop
- FHWA-NHI-136106W Developing a Transportation Asset Management Plan

Business, Public Admin, and Quality
- FHWA-NHI-310109 Federal-Aid 101 (FHWA Employee Session)
- FHWA-NHI-310110V Federal-Aid Highways-101
- FHWA-NHI-310119V Writing Effective Program Review Reports: Moving People to Action
- FHWA-NHI-310123V FHWA Basic Contracting Officer's Representative (COR) Training

Construction and Maintenance
- FHWA-NHI-134001V Principles and Applications of Highway Construction Specifications
- FHWA-NHI-134005V Value Engineering (3-day version)
- FHWA-NHI-134005W Value Engineering (4-day version)
- FHWA-NHI-134005X Value Engineering (5-day version)
- FHWA-NHI-134006V Utility Coordination for Highway Projects
- FHWA-NHI-134037V Managing Highway Contract Claims: Analysis and Avoidance
- FHWA-NHI-134063V Maintenance Leadership Academy

Design and Traffic Operations
- FHWA-NHI-133121V Traffic Signal Design and Operation
- FHWA-NHI-133122V Traffic Signal Timing Concepts

Environment
- FHWA-NHI-142078A Planning and Environmental Linkages (PEL), without Implement PEL Activity
- FHWA-NHI-142078V Planning and Environmental Linkages (PEL)

Financial Management
- FHWA-NHI-231033V Public-Private Partnerships (PPP)

Highway Safety
- FHWA-NHI-380077V Intersection Safety Workshop
- FHWA-NHI-380078V Signalized Intersection Guidebook Workshop
- FHWA-NHI-380089V Designing for Pedestrian Safety
- FHWA-NHI-380090V Developing a Pedestrian Safety Action Plan
- FHWA-NHI-380091V Planning and Designing for Pedestrian Safety
- FHWA-NHI-380096V Modern Roundabouts: Intersections Designed for Safety
- FHWA-NHI-380109V Alternative Intersections and Interchanges

Hydraulics
- *COMING SOON*-FHWA-NHI-135027V Urban Drainage Design
- *COMING SOON*-FHWA-NHI-135056V Culvert Design
- FHWA-NHI-135095V Two-Dimensional Hydraulic Modeling of Rivers at Highway Encroachments

Pavement
- FHWA-NHI-131139V Constructing and Inspecting Asphalt Paving Projects

Structures
- FHWA-NHI-130053V Bridge Inspection Refresher Training
- FHWA-NHI-130053A Bridge Inspection Refresher Training
- *COMING SOON*-FHWA-NHI-130092V Load and Resistance Factor Rating of Highway Bridges
- *COMING SOON*-FHWA-NHI-130093A Displacement-Based Seismic Design of Bridges
- FHWA-NHI-130125V Tunnel Safety Inspection Refresher ILT
- *COMING SOON*-FHWA-NHI-130126V Strut-and-Tie Modeling (STM) For Concrete Structures

A Modern Tool for Noise Analysis

by **AILEEN VARELA-MARGOLLES**

Highway traffic creates noise—and sometimes the negative impacts of noise in an area need to be mitigated or minimized. To do so, a project team must first conduct a highway traffic noise analysis to determine whether noise impacts exist and to consider and design potential mitigation measures—noise abatement—to reduce those impacts. Designing noise abatement requires understanding basic acoustic principles, regulatory requirements, public expectations, and some engineering considerations.

To assist with regulatory compliance related to noise impact determinations and noise abatement design, the Federal Highway Administration created the Traffic Noise Model (TNM) software. The TNM line of software packages has been around for over two decades. FHWA released TNM 3.0 in February 2020 and will soon release the next version, TNM 3.1.

FHWA worked closely with the Volpe National Transportation Systems Center to complete the version 3.1 update. The development focused on fixing software bugs and addressing feedback and feature requests from active TNM 3.0 users.

Increased Functionality

TNM 3.1 now includes an installer, parallel processing of receivers, and removal of the database saving structure. The updates should decrease the memory usage and runtimes of the software.

TNM 3.1 corrects some minor acoustical calculation issues from TNM 3.0, although there have been no changes to the underlying acoustical assumptions or metrics since the last release. The developers updated the data model for TNM 3.1 with improved error checking and error handling compared to TNM 3.0, so that version 3.1 can provide results for project models that would have errored out in TNM 3.0.

TNM 3.1 also offers an improved user interface and data connections. These changes were made in response to detailed user feedback regarding important functionality and data visibility required to conduct a highway traffic noise analysis on a typical project. For example, the Barrier Design Table now shows sound source contributions by barrier segment and offers the ability to filter and sort the data in the table. TNM 3.1 also enables the user to import existing TNM model files that include coordinate systems, projections, and adjustments. For more information regarding the updates, please see the Release Notes and TNM 3.1 Fact Sheet at *www.fhwa.dot.gov/environment/noise/traffic_noise_model/tnm_v31/index.cfm*.

To further expand TNM's functionality, FHWA is developing a Noise Screening Tool that allows simplified inputs and outputs to enable users to determine the likelihood of noise impacts occurring before engaging in a full-scale noise analysis.

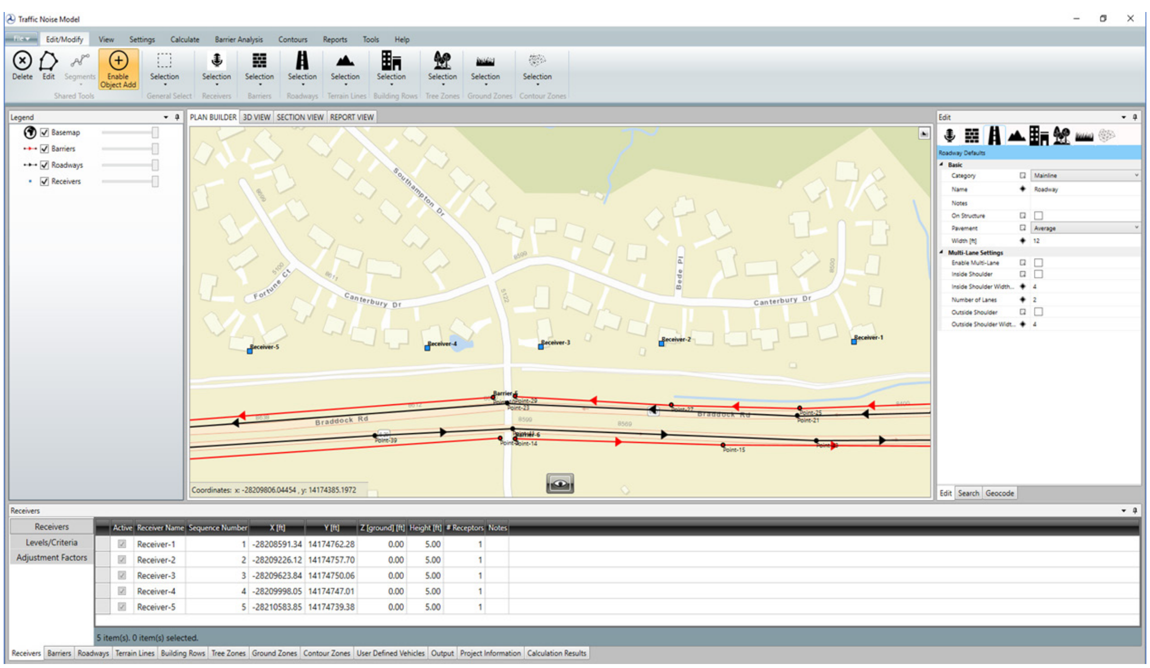
Ongoing Maintenance and Future Enhancements

FHWA has set a target schedule to provide annual or semi-annual releases of TNM. This will enable the development team to respond quickly to user requests, enhancement ideas, and new software programing protocols. The TNM 3.0 acoustics and TNM 3.1 functionality will be used to update the Roadway Construction Noise Model (RCNM). In addition, the team is evaluating whether it is possible to integrate TNM and RCNM into a single highway noise model.

FHWA continues to engage the user community through training, regular email updates, and meetings. For further information on using TNM, visit the instructional demonstration videos on the TNM playlist at *www.youtube.com/playlist?list=PL5_sm9g9d4T3naH9knm5E6SZUpmI_QD3y*. The FHWA Resource Center also offers training via a multi-day course. The lessons are currently instructor-led, but virtual.

For more information, contact Aileen Varela-Margolles at *a.varela-margolles@dot.gov*.

AILEEN VARELA-MARGOLLES is an environmental specialist on the Air Quality and Noise Team in FHWA's Office of Environment, Planning, and Realty.



This screenshot of the TNM 3.1 Graphical User Interface displays the various areas and windows available for the user to input and review data. The main window is a streetview map of the example project area.

Source: FHWA.

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

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

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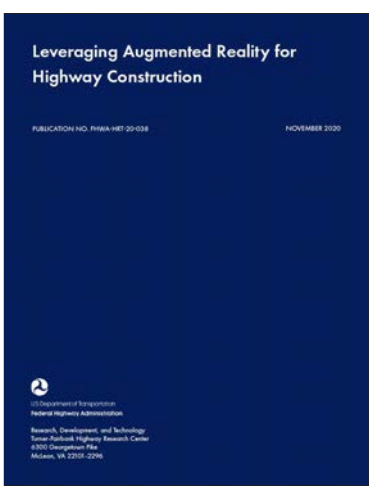
Leveraging Augmented Reality for Highway Construction

Publication Number: FHWA-HRT-20-038



Augmented reality (AR) is an immersive technology combining computer-generated information with real-world imagery in real time. AR enhances the user's perception of reality and enriches information content. Challenges in highway construction management and field operations include the lack of real-time and integrated information, gaps between planned solutions and practical implementations, quality assurance, and effective project communications. Three-dimensional (3D) model-based design and construction workflows are becoming more common on highway projects, and the Federal Highway Administration is promoting these and other innovations through its Every Day Counts program and Building Information Modeling efforts.

The increased use of 3D model-based workflows and rapid advancement in computer interface design and hardware make AR a tool for overcoming these construction challenges. Enriched content can help project managers and engineers deliver projects faster, safer, and with greater accuracy and efficiency. This study focused on documenting current AR technologies and applications, with an emphasis on the state of the practice for using AR technologies in design, construction, and inspection applications for highways, and includes a literature review and interviews with researchers and vendors.

The publication is available at *www.fhwa.dot.gov/publications/research/infrastructure/pavements/20038/20038.pdf*.

Utilizing Mobile Ad Hoc Networks to Enhance Road Safety

Publication Number: FHWA-HRT-20-046

Analyses by the National Highway Traffic Safety Administration concluded connected vehicle innovations could reduce crashes, injuries, and fatalities by 50 percent. There are places and times, however, where there will be a need to supplement connected vehicle systems—for example, in rural areas where there may not be enough traffic for connected vehicle systems to be viable, or during events when crowds may overwhelm systems working well during normal operations.

FHWA's Exploratory Advanced Research Program supports studies investigating the use of mobile ad hoc networks (MANETs) to enhance road safety for all users. MANETs are a way to communicate on the fly with available hardware and software. MANETs require minimal infrastructure and can be created autonomously as desired. They have been used primarily in military applications and in disaster relief efforts, but have not yet been used for transportation safety.

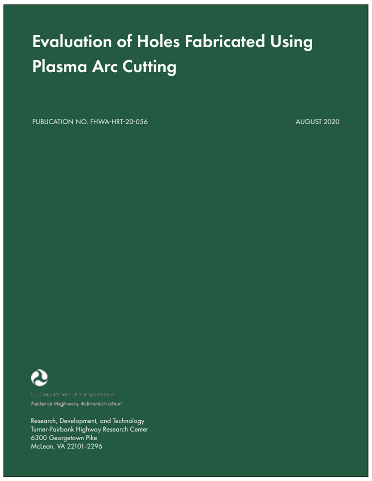
One scenario involves smartphones from nonmotorized travelers directly sending automatic, periodic geographical broadcast messages via a mobile application to nearby vehicles, which, in turn, send the information to following vehicles. This method eliminates the need to ping other vehicles about the nonmotorized traveler's location and alerts vehicles to their location more quickly.

Researchers at the University of Virginia are exploring how to deploy MANETs in areas and scenarios with less infrastructure, such as when pedestrians and bicyclists cross at the mid-block and in more rural or remote settings. At the University of Wisconsin–Madison, researchers look to harness MANETs to alert vehicles to pedestrian and bicyclist crossings at intersections through a mobile application.

The publication is available at *www.fhwa.dot.gov/publications/research/ear/20046/20046.pdf*.

Evaluation of Holes Fabricated Using Plasma Arc Cutting

Publication Number: FHWA-HRT-20-056



This report documents fatigue and tensile test results of steel plates with round holes fabricated using plasma arc cutting. Bridge owners, designers, and fabricators have shown interest in using plasma arc cutting as a more economical alternative to traditional hole fabrication methods. However, a lack of experimental data demonstrating the behavior of plasma-cut holes under fatigue and tensile loading has hindered their use in steel bridge design and fabrication. FHWA initiated the study to categorize the fatigue and static tension resistance of plasma-cut holes in steel bridge members.

Modern plasma-cutting equipment and techniques can produce high-quality holes more economically than drilling and punching. However, design and construction specifications from the American Association of State Highway and Transportation Officials do not permit the use of plasma-cut holes in primary bridge members because of a lack of experimental data demonstrating their fatigue and tensile strength. Additionally, it is uncertain if holes fabricated using plasma arc cutting meet the AASHTO requirements for accuracy of hole size.

This research establishes the design fatigue resistance and assesses the fracture behavior of steel members with plasma-cut holes. Researchers evaluated multiple plasma-cutting processes. Results showed that the fatigue resistance of plasma-cut holes is lower compared to current hole-making methods. The researchers found that open holes fabricated using plasma arc cutting are an AASHTO category E fatigue detail, representing lower fatigue resistance compared to drilled or punched holes. Tensile testing showed certain plasma-cutting processes could cause brittle failure modes in tension members with plasma-cut holes.

The publication is available at *www.fhwa.dot.gov/publications/research/infrastructure/structures/bridge/20056/20056.pdf*.

Learning About Driver and Pedestrian Behaviors Through Connected Simulation Technology

Publication Number: FHWA-HRT-20-059

As the Nation's roadways increase in connectivity and complexity, a challenge emerges to maintain road safety and mobility for all roadway users. Examining how vehicles and pedestrians share the road is one key way to improve road safety, especially considering increased pedestrian deaths by motor vehicle crashes. In 2018, there were 6,283 reported pedestrian fatalities due to car crashes, the most since 1990. This report provides a description of the research carried out to improve the understanding of connected simulated technology and how to expand the study of interactions between drivers and pedestrians, impacting the creation of technologies involving safety and mobility.

FHWA's Exploratory Advanced Research Program has been supporting research examining simulated traffic interactions between drivers and pedestrians to better understand how they communicate with each other and the resulting impacts on driver and pedestrian behaviors. The University of Iowa conducted a research project using real-life drivers and pedestrians along with simulated vehicles and pedestrians in a connected driving simulation. The researchers successfully created a connected simulation environment, linking a pedestrian simulator and a driving simulator by bridging differing software systems—a large technical challenge of the project.

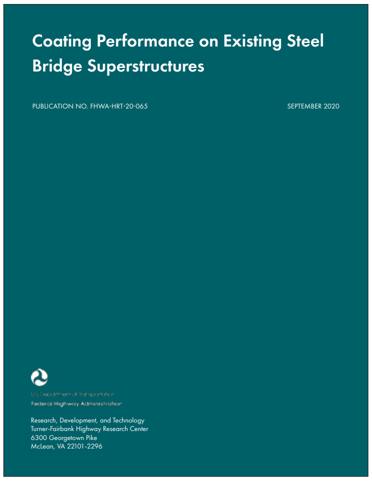
Based on the connected simulation technology, the researchers explored the relationship between glances and gestures pedestrians may make toward oncoming traffic as they attempt to cross a roadway. This study was facilitated using 3D avatars, which the Iowa team customized for the research project. The project resulted in the development of mixed-mode technology with connected driving and pedestrians through the use of graphical avatars, representing the live actions and movements of drivers and pedestrians.

Additionally, the study yielded new methods of scenario control and data analysis suited for multiparticipant simulation research. Although participants stated that most of the time they could not distinguish the real participants from the simulated ones, the results suggest real study participants do behave differently with each other than with simulated pedestrians and vehicles.

The publication is available at *www.fhwa.dot.gov/publications/research/ear/20059/20059.pdf*.

Coating Performance on Existing Steel Bridge Superstructures

Publication Number: FHWA-HRT-20-065



Coating Performance on Existing Steel Bridge Superstructures

PUBLICATION NO. FHWA-HRT-20-065

SEPTEMBER 2020

U.S. Department of Transportation
Federal Highway Administration

Research, Development, and Technology
Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, VA 22101-2296

Steel corrodes when exposed to moisture and oxygen. If left unprotected, some steel used in highway bridge superstructures is highly susceptible to corrosion when exposed to the environment. The corrosion process is significantly accelerated in the presence of salts. Corrosion on highway bridges is predominantly caused by chloride ions from either deicing salts or natural chlorides present in certain environments.

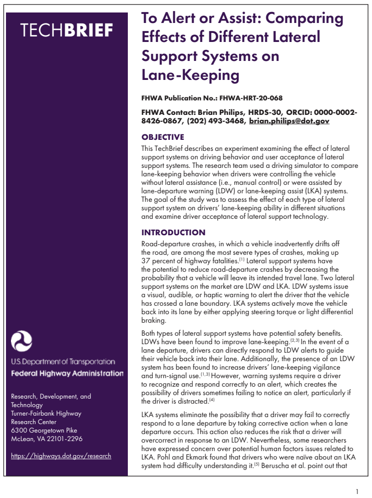
This study evaluated the performance of four coating systems applied on chloride-contaminated steel substrates. The purpose of the study was to identify coating systems that can provide extended service life for steel bridges with minimal surface preparation at a much-reduced cost. The study helps estimate the amount of chloride contamination coating systems can tolerate without significant premature failure.

The chloride contamination levels tested in this study were 0, 20, and 60 micrograms per cubic centimeter. The coating systems tested were two three-coat systems (one with inorganic zinc-rich primer and the other with organic zinc-rich primer), a two-coat system with carbon nanotubes in its zinc-rich primer, and a one-coat system of high-ratio calcium sulfonate alkyd. Coated panels were exposed to two conditions: accelerated laboratory testing and outdoor natural weathering. The three-coat systems had the best corrosion protection performance among the tested specimens. The inorganic zinc primer performed slightly better than the organic zinc primer. The two-coat system demonstrated the highest adhesion strength over all levels of chloride contamination.

The publication is available at *www.fhwa.dot.gov/publications/research/infrastructure/structures/bridge/20065/20065.pdf*.

To Alert or Assist: Comparing Effects of Different Lateral Support Systems on Lane-Keeping

Publication Number: FHWA-HRT-20-068



TECHBRIEF

To Alert or Assist: Comparing Effects of Different Lateral Support Systems on Lane-Keeping

FHWA Publication No.: FHWA-HRT-20-068

FHWA Contact: Brian Philips, HRDS-30, ORCID: 0000-0002-8426-0867, (202) 493-3468, brian.philips@dot.gov

OBJECTIVE

This TechBrief describes an experiment examining the effect of lateral support systems on driving behavior and user acceptance of lateral support systems. The research team used a driving simulator to compare lane-keeping behavior when drivers were controlling the vehicle without lateral assistance (i.e., manual control) or were assisted by lane-departure warning (LDW) or lane-keeping assist (LKA) systems. The goal of the study was to assess the effect of each type of lateral support system on drivers' lane-keeping ability in different situations and examine driver acceptance of lateral support technology.

INTRODUCTION

Road-departure crashes, in which a vehicle inadvertently drifts off the road, are among the most severe types of crashes, making up 37 percent of highway fatalities.[1] Lateral support systems have the potential to reduce road-departure crashes by decreasing the probability that a vehicle will leave its intended travel lane. Two lateral support systems on the market are LDW and LKA. LDW systems issue a visual, audible, or haptic warning to alert the driver that the vehicle has crossed a lane boundary. LKA systems actively move the vehicle back into its lane by either applying steering torque or light differential braking.

Both types of lateral support systems have potential safety benefits. LDWs have been found to improve lane-keeping.[2,3] In the event of a lane departure, drivers can directly respond to LDW alerts to guide their vehicle back into their lane. Additionally, the presence of an LDW system has been found to increase drivers' lane-keeping vigilance and turn-signal use.[1,3] However, warning systems require a driver to recognize and respond correctly to an alert, which creates the possibility of drivers sometimes failing to notice an alert, particularly if the driver is distracted.[4]

LKA systems eliminate the possibility that a driver may fail to correctly respond to a lane departure by taking corrective action when a lane departure occurs. This action also reduces the risk that a driver will overcorrect in response to an LDW. Nevertheless, some researchers have expressed concern over potential human factors issues related to LKA. Pohl and Ekmark found that drivers who were naïve about an LKA system had difficulty understanding it.[5] Beruscha et al. point out that

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https://highways.dot.gov/research

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This study assessed the influences of lateral support systems on lane-keeping. Participants were divided into three conditions: LDW, LKA, and manual driving. The experiment used simulated wind gusts to induce lane departures throughout the drive. Participants in the LDW condition spent less of the drive outside of their lane, returned to their lane more quickly when a lane departure occurred, and held a more constant position while in their lane. Lane-keeping for drivers in the LKA condition did not match those in the better lane-keeping LDW condition, but the group showed reduced lane-departure durations relative to those in the manual driving condition. Participants in the manual driving condition also showed reduced travel speeds relative to those in the LDW or LKA conditions, suggesting that the difference in lane-keeping was not due to a lane-keeping/speed tradeoff. In fact, participants in the LKA condition maintained similar levels of lane-keeping compared to participants in the manual condition while driving more quickly, indicating LKA improved drivers' lane-keeping ability. The findings speak to the potential usefulness of lateral support systems for reducing lane departures.

The publication is available at *www.fhwa.dot.gov/publications/research/safety/20068/20068.pdf*.

NATIONAL WORK ZONE AWARENESS WEEK

April 26–30, 2021

Drive Safe. Work Safe. Save Lives.

Work zones play a critical role in the preservation and enhancement of our Nation's roadways. However, changes to traffic patterns and rights of way due to work zones, combined with the presence of workers and the frequent movement of work vehicles, may lead to crashes, injuries, and fatalities.

It's important for everyone to do their part to be safe. To protect field workers and all road users, follow these tips for traveling safely through work zones:

- Know before you go
- Stay alert and obey the roadway
- Watch for workers
- Watch for sudden stops
- Slow down
- Use caution around large vehicles

For more information and resources, 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**.

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