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Summer 2020

LAVA ROADS

Hawaii eruption events create unique challenges

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- Augmented Reality: New Age of Construction Solutions

U.S. Department of Transportation
Federal Highway Administration

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FEATURES

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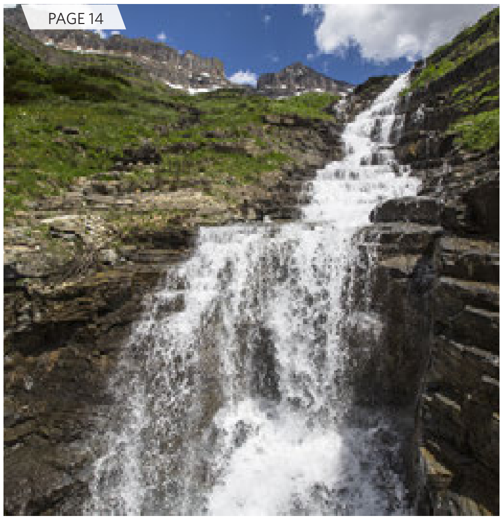

Source: NPS.

DEPARTMENTS

COVERS and ABOVE—Lava pushes forward in the Puna district of the island of Hawaii on May 28, 2018.

Source: Sgt. 1st Class Thomas Wheeler, State of Hawaii, Department of Defense.

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Investing in Small Businesses Fuels Transportation Innovation

Entrepreneurs spur growth throughout the United States by starting small businesses and by creating new technologies. Small businesses are perfectly poised to rapidly research, develop, and commercialize technologies that address the Nation's most pressing transportation challenges. Apple®, Amazon®, Google™, Nest®, and Yahoo!® all started out as small businesses—and now they are household words.

The U.S. Department of Transportation's Small Business Innovation Research (SBIR) program, one of 11 Federal SBIR programs, is an engine of growth in the transportation economy. USDOT awards contracts to domestic small businesses in relevant research areas. The program provides funding for entrepreneurs to develop new transportation technology and associated applications. Over the past 5 years, USDOT has spent $50 million to fund small businesses. The Department's operating administrations, such as the Federal Highway Administration and the Federal Motor Carrier Safety Administration, are integral to supporting the Department's SBIR awards activity.

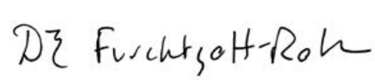
Entrepreneurs have notched impressive results from their participation in USDOT's SBIR program. One company, Pulsar Informatics, developed a trucking fatigue meter that lets different users—such as trucking companies, individual drivers, and insurance firms—know how the risk of fatigue affects driver safety, performance, and cost. New infrared sensing technologies from Fuchs Consulting, Inc., can detect subsurface damage in concrete and measure steel stress levels in bridges, enabling faster detection of deterioration and repairs. Tool, Inc., developed prototype seatbelt locking mechanisms that reduce the risk of children getting trapped in their seat belts.

"Everybody Wins," on page 22 in this issue of *Public Roads*, focuses on two small businesses, Intelligent Automation, Inc., and ZKxKZ, Inc. Working with FHWA, they are taking different approaches to develop and deploy new technologies to improve highway operations and safety. Intelligent Automation, Inc., is using artificial intelligence to optimize traffic flows. ZKxKZ, Inc., is developing innovations in mini-roundabout installation and materials.

Entrepreneurs excel in part because they have new ideas, they are free from bureaucratic constraints, and their small size enables them to be nimble agents of change. USDOT is expanding its role in supporting innovation in the private sector. For example, this year the Department held a virtual "Pitch Day" in late May for small business owners who have applied to this year's SBIR solicitation and were selected to present. Pitch Day is modeled on a similar Air Force event, where entrepreneurs can come and present their ideas, engage in a question and answer period with topic experts, and quickly hear about funding. For USDOT, this new process will result in contracts being awarded in weeks instead of months, so that small businesses can begin their work and receive funding sooner.

The SBIR program has funded thousands of entrepreneurs, many of whom are working toward commercializing their ideas. Jacob Crossman, a senior research engineer at SBIR beneficiary Soar Technology, says, "Without SBIR, Soar Technology would not have been able to execute this level of research and development internally." Soar Technology is working on a technology that can help solve the problem of handoff in limited autonomy vehicles.

The Department would like to give entrepreneurs more awards for promising technology. This Federal support of entrepreneurs helps expand research into new transportation technologies that can improve our lives, our transportation system, and our economy.



Diana Furchtgott-Roth
Deputy Assistant Secretary
for Research and Technology
U.S. Department of Transportation

From the Center for Local Aid Support

Building a Road to Success in the Age of Digital Learning

by **TRINETTE BALLARD**

Partners of the Center for Local Aid Support offer more than 400 courses on transportation topics such as pavement preservation and environmental protections.

Source: FHWA.

When it comes to the benefits of digital learning, together everyone achieves more. The Center for Local Aid Support (CLAS) in the Federal Highway Administration's Office of Innovative Program Delivery built a support system to sponsor online learning opportunities for a changing transportation workforce and a fast-moving transportation industry. The center's focus is on capacity building and ensuring that opportunities for professional growth and development are available 24/7 to local agencies and Tribes.

"Learning never stops even when you are a seasoned professional working in the transportation field," says Victoria Peters, director of CLAS. "Today's technology is not only enhancing our highway infrastructure; it is changing the way we learn. CLAS is integrating digital learning into our programs to help professionals keep pace."

CLAS has established several partnerships that are making around-the-clock training available online to local agencies and Tribes to improve their transportation programs, policies, and processes.

"For decades, NACE has not had a more valuable Federal partner than FHWA," says Kevan P. Stone, the executive director of the National Association of County Engineers (NACE). "The opportunity for our members to continually build their skills and be introduced to cutting-edge innovation has been immeasurable and undoubtedly saved lives. The CLAS team represents the very best of FHWA, and the ever-changing local infrastructure landscape will make them a vital support source for years to come."

Increasing Access to Continuous Learning

Capacity building is part of a continuous, long-term, strategic change process that can shift how transportation professionals think about and operate their highway system.

"Taking on a new job, trying a new process, or doing something new requires learning," says Peters.

The availability of online learning courses offers convenience and saves time for an industry that never stops. CLAS provides training on innovative practices and the latest advancements through its bimonthly Innovation Exchange webinars and encourages dialogue among the participants in the webinars.

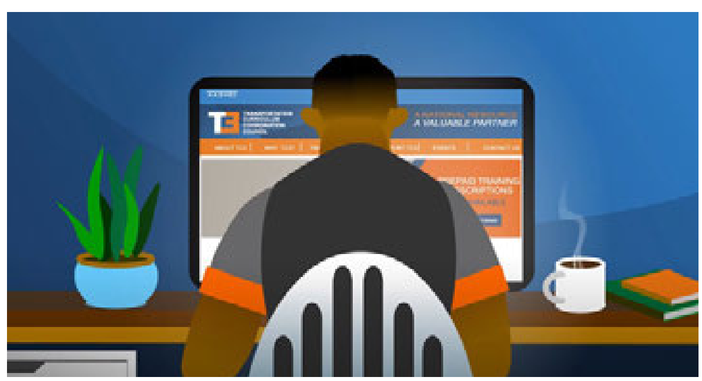
In addition, CLAS sponsors online access to over 400 transportation training modules through partnerships with the American Association of State Highway Transportation Officials, the Institute of Transportation Engineers, and the National Highway Institute.

"I am thankful for [these organizations'] willingness to partner with FHWA to make their online resources available to complement the longstanding training and technical assistance provided by the Local Technical Assistance and Tribal Technical Assistance Programs," says Peters. "We all have a commitment to making the local transportation workforce stronger."

Despite having a small team with many partners, CLAS has big goals to improve transportation for its local and Tribal customers.

"Our team is proud of the differences we are making in the transportation industry and we are even more proud that we are able to transform transportation as members of FHWA," says Peters.

For more information on the Center for Local Aid Support and available online training, visit *www.fhwa.dot.gov/clas*.



CLAS sponsors online training for local and Tribal transportation agencies, such as courses from the American Association of State Highway and Transportation Officials' Transportation Curriculum Coordination Council (TC3).

Visit *https://youtu.be/pTMy29r5ICU* for more information.

Source: FHWA.

TRINETTE BALLARD is a program manager with CLAS. She has worked for FHWA for 12 years.

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CALL FOR ABSTRACTS

Do you have research results or a program success story to share?*
Are you using state-of-the-art technology or innovative methods that have had a positive effect on your program? Do you know of a good story that would be of interest to fellow highway professionals? If so, share your idea for a possible article in *Public Roads*. Promote your work while providing readers with valuable data, insights, and lessons learned.

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- Include the primary author's name, title, and affiliation, as well as the email address, phone number, and mailing address for all authors
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* Ideas submitted by FHWA and State DOT authors preferred. Other Federal agencies, local and Tribal DOTs, field researchers and practitioners, and academia are also welcome to submit ideas but are encouraged to collaborate with FHWA or State DOTs.

Collaborate with CARMA

FHWA's software platform is facilitating a transportation transformation through automated vehicles.

These CARMA3 vehicles are equipped with the CARMA platform, which enables communication between vehicles and roadway infrastructure. *Source: FHWA.*

The Cooperative Automation Research Mobility Applications (CARMA) platform equips vehicles with the ability to interact and cooperate with roadway infrastructure and other vehicles—ultimately improving efficiency and safety and transforming transportation systems management and operations.

CARMA is an open source software platform that runs on a computer installed in a vehicle. The computer interacts with the vehicle's devices to enable cooperative automated vehicle maneuvers.

Join the Collaborative

The CARMA Collaborative is a growing community of CARMA users invested in developing intelligent transportation solutions. Please share this information with your professional associates.

FHWA created the platform to be vehicle and technology agnostic, enabling a wide range of participants in the transportation industry to test it on their own vehicles. CARMA's innovative approach and design encourages collaboration with industry, academia, and other public agencies on cooperative automation applications.

For more information, visit https://highways.dot.gov/research/research-programs/operations/CARMA or contact Taylor Lochrane at Taylor.Lochrane@dot.gov.

U.S. Department of Transportation
Federal Highway Administration

CAN AUGMENTED REALITY ADDRESS HIGHWAY CONSTRUCTION CHALLENGES?

FHWA conducted a study to explore the possibilities for AR technology in roadway construction.

Portable hand-held devices with augmented reality capabilities have the potential to help with onsite highway projects.

© 2019 Trimble.

by **HODA AZARI** and **KEVIN GILSON**

Field operations in the transportation sector present many challenges. Among them are the lack of real-time and integrated information, gaps between planned solutions and practical implementations, quality assurance, and communications among project participants. As a result of the rapid advancement in computer interface design and hardware, augmented reality (AR) may be a tool to help overcome some of these obstacles.

AR offers an immersive technology that overlays virtual computer-generated information with the real environment in real time, enhancing the user's perception of reality and enriching the provided information content. This blending of project-specific information with the real-world site view can assist project managers and engineers with the delivery of their projects in a safe and timely manner and with greater efficiency and accuracy. In addition, with the ability to navigate through all phases of a construction project, managers can detect errors before they occur or change the design and construction details.

"Considering AR's benefits and success in the entertainment and video game industries, leveraging AR appears to be an opportunity in construction management for highway infrastructure assets," says Dr. Kelly Regal, Associate Administrator, FHWA Office of Research, Development, and Technology.

Over the last year, FHWA conducted a comprehensive study to investigate available AR technologies, their reliability and practical application, and how these technologies can be applied to construction management. The results of that study follow.

Hand-held or Head-mounted?

There are two basic categories of display types in AR systems: hand-held mobile devices, such as smartphones and tablets, and head-mounted display (HMD) devices, such as headsets or glasses. Primary differences include the way each device displays imagery to users and how the devices track their position relative to the real world.

Hand-held devices are typically video see-through displays that use the back-facing cameras on the device to capture video of the real-world environment and display that image on the front screen. With these displays, the device needs to be held close to eye level and at arm's length to capture the widest field of view—which can be difficult over long periods of time and challenging in a construction site environment. Hand-held devices typically use a global navigation satellite system (GNSS) to determine the initial user location within a few meters, and then use the inertial movement of the device to change the view as the device is moved around.

Some vendors have demonstrated prototype applications that optically track the imagery in the video feed to support registration with the real-world view and track movement. Many commercially available AR applications use a marker-based positioning tool, where a target is placed in the real world and viewed by the video feed to register real-world position relative to the virtual model.

Several off-the-shelf AR applications enable the user to display a 3D model over the live video feed of a mobile device. The application is given a "target" image, either graphical (for example, a plan or rendering) or a photograph. The image is printed out, and the application on the mobile device recognizes the target image and displays the 3D model in alignment as defined in the application. The model view is locked to the position of the target image in the video feed.

HMDs are typically optical see-through displays where the device's view of the real world is overlaid by a virtual computer-generated image. These devices offer more immersive and realistic experiences than hand-held devices because the real-world view is direct and the virtual view is typically stereoscopic. The scene changes as the user's head moves. Some HMD devices have built-in audio commands to change the view parameters. The audio controls help maintain hands-free operation. HMDs are typically outfitted with more sophisticated and accurate tracking technology than off-the-shelf hand-held devices, as the blending of virtual imagery and the direct view out of the device requires more precise alignment of the imagery for true immersion and user comfort. Like hand-held devices, the user's initial positioning with an HMD relies on GNSS tracking or a marker in the field.

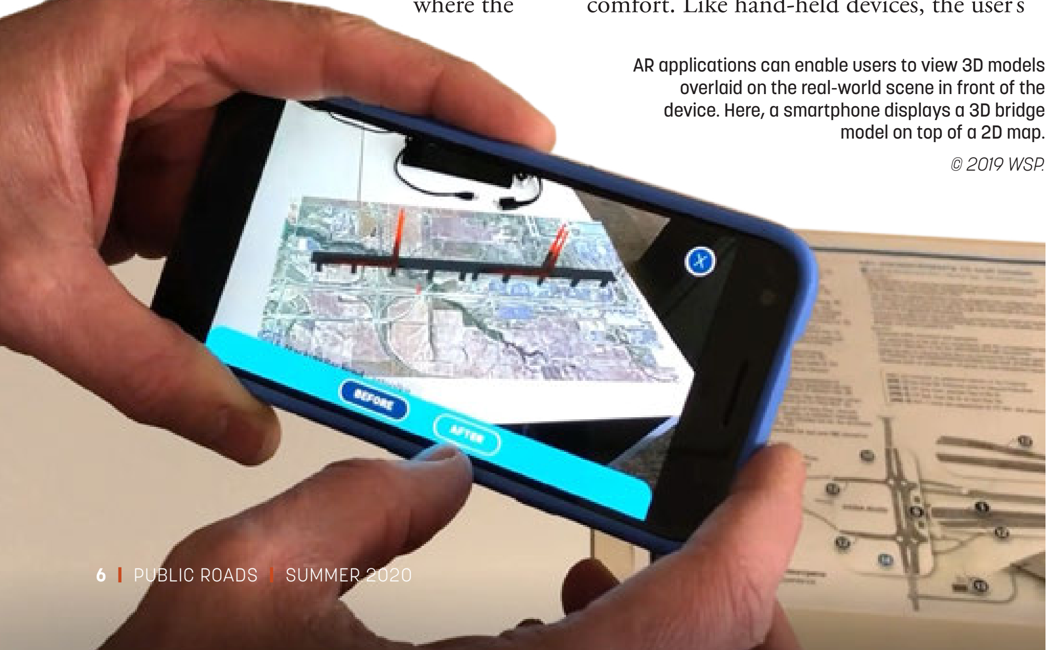
A user views a 3D bridge model, also projected behind him, using an AR head-mounted display. His hand gestures and finger movements enable him to navigate within the AR view.

© 2019 WSP.

Some AR HMD devices can leverage the 3D scanning hardware used for AR tracking to capture existing 3D data in the field. The user views these virtual model elements superimposed over the real-world view and can line up the model elements to identical elements in the real world. The precision of the data depends on several factors, including available site survey information and the scanning precision of the sensor hardware.

"On a typical highway construction site with good survey targets and a robust 3D-model-based workflow, this ability to capture accurate data in real time using only an HMD device can become an option for site inspections," says Katherine Petros, leader of the Infrastructure Analysis and Construction Team in FHWA's Office of Infrastructure Research and Development.

Tablet devices are making more rapid advances than HMD devices in the highway construction field because they have comparatively fewer display and viewing limitations. The tradeoff is less accurate tracking technology, and therefore, less precision of the registration of virtual to real-world imagery. However, industry researchers are trying to develop tablet devices with integrated special hardware and software to provide greater precision tracking and better registration of virtual 3D data to the real-world view.



AR applications can enable users to view 3D models overlaid on the real-world scene in front of the device. Here, a smartphone displays a 3D bridge model on top of a 2D map.

© 2019 WSP.

Challenges for AR Systems in Construction Environments

Construction sites—especially highway construction sites—are particularly challenging for AR systems. Highway projects are typically made up of large, smooth, and flat objects lacking in fine details, making it more difficult for AR systems to track their location within the scene. Additionally, it is difficult for 3D modeling applications to represent these types of objects to be easily recognized by the user and the AR system. As a result, these elements require more preparation for their use in AR systems.

In addition, there are several technological barriers. AR systems require significant processing power and enough onboard storage to concurrently support tracking processes and the real-time display of the virtual 3D model. To be useful in a construction environment, AR devices must be standalone and portable, which means processing for tracking and display must be on board the device, not augmented by an external source. Some systems are tethered to a separate wearable computing device that reduces the necessary weight on an HMD. Larger 3D models, more accurate tracking, and increased display quality require more processing power. As AR systems evolve, there will be a tradeoff between performance of the system and the size, weight, and comfort of the AR device.

The brightness of the real-world environment presents a key challenge with HMDs. Typical highway construction sites are outdoors and bright, which limits the quality and usefulness of most current AR HMD devices. Bright, open environments are more challenging for the tracking technology to follow. Hand-held devices control the real-world display on the screen—the video display and virtual displays are better matched in overall brightness, providing better quality and greater realism.

"In the near term," says Adrien Patané, a regional manager with an AR technology designer and manufacturer, "hand-held devices likely provide better opportunities for AR on outdoor construction locations."

Another drawback of both hand-held and HMD devices is the limited field of view of the overlaid virtual model presented to the user. Users must pan around with the device or turn their head back and forth to view a large area, which could be prohibitive over long periods.

Another technological challenge with AR systems is occlusion, or masking of hidden elements, which may be needed in complex construction environments. When the occlusion is ignored or displayed poorly, it negatively impacts the realism and immersive quality of the displayed scene.

AR systems also present difficulties because of the safety risks on a construction site. Like any display device, some user attention will be focused on the device and not entirely on the surroundings. Hand-held devices are held in front of the user, require the use of at least one hand, and can block visibility. HMDs can limit the user's peripheral view and block ambient sounds.

Highway designers and builders can view design data overlaid on a real-world, existing construction site. Here, the overlaid lines show the wireframe and surface geometry from the design data.

It may be possible to address this challenge in the future if devices could be designed to recognize safety issues and risks for the user by knowing the user's precise location on the site.

AR Applications for Highway Construction

Industry and technology manufacturers are developing AR applications for construction to display annotations and graphical information that enhance the understanding of real-world objects, combined with increased locational accuracy. In addition, 3D design and construction models can be overlaid, in their real-world position, in the view of the existing environment.

AR technology can display what is not yet constructed, enabling users to see 3D design models in the real-world context. It provides the user with the opportunity to compare design alternatives in context, check relationships between existing and future elements, monitor site logistics and equipment movements, and illustrate construction methods and sequencing.

After construction, AR can overlay and compare 3D design models (design intent) onto the end result in the field to inspect the construction, monitor compliance with codes and standards, and check quantities and work progress.

AR also can display existing elements that are not visible to the user in the real world, such as buried utilities or structural components or other elements obstructed from the current view. AR can show abstract information, such as alignment information, easements, site and right-of-way boundaries, environmental boundaries such as flood levels or sea-level rise data, potential work zone hazards, and metadata tagged to real-world objects. AR can also display unsafe areas and risks or guide users securely through a construction site.

AR systems prove useful for construction inspection—for example, for measuring areas of newly installed concrete pads to calculate contractor payment amounts. The user can capture points with the AR device using finger gestures and a cursor placed over real-world points, and the device measures the areas of the surface enclosed. AR technologies can also be complemented by distance measurement capabilities, which enhance engineering and inspection functions by being able to observe distances between reality and proposed designs.

Most platforms for 3D design applications support review and collection of data in the field through mobile devices. The field data are then synchronized with project models and data in the office. This provides an opportunity for collaboration between the field and office and ensures that the user with the device always has the latest, correct version of the model, which may also serve as a digital as-built to be used in future. While most of the tools offer ways of optimizing models and model display on mobile devices with more limited processing power and storage, this optimization will be even more important for AR devices and applications that require enough graphics performance to support real-time stereoscopic rendering of the 3D models.

UDOT's Perspective

Since 2016, the Utah Department of Transportation (UDOT) has been awarding select projects using 3D models as the legal document (MALD). To date, UDOT has awarded 11 projects with MALD, and fully constructed 8 of them. Although most of these projects also have included paper plan sets for information only, UDOT inspectors and contractors have used survey rovers and mobile devices (with the 3D design model loaded) in lieu of the plans sets. In fact, while most construction crews began projects referencing the paper plan sets, all have stated that the use of mobile devices was easier and more efficient than using the plan sets.

In 2018, UDOT awarded its first project with MALD only, without creating and printing plan sheets. That project success led UDOT to forgo cutting sheets on later projects with MALD. The success of using mobile devices in the field is a significant precursor to the promise of AR use.

UDOT has used vendor apps on tablets in the field to inspect projects with MALD. However, these tools have not been user-friendly, and model authors have complained about added time when checking that their design information is transferred to the mobile device.

UDOT's geographic information system (GIS) group has developed user-friendly solutions that can be applied in the field with a phone or tablet. UDOT construction inspection crews have been pleased with the tools, which led to UDOT developing additional workflows for GIS tools in the field. In addition, UDOT is experimenting with the ability of these tools to also write digital information to a central set of databases, expecting the practice to replace paper or PDF plan sheet as-builts.

"Expanding the availability of 3D design models in the field with vendor apps or GIS tools will lead to a smooth transition to AR, likely on multiple platforms," says George Lukes, a standards and design engineer with UDOT.

UDOT has worked with vendors on construction projects with AR. The tool UDOT tested could extract all of the features in the 3D design model. While the user held a mobile device, the features were projected on the screen in real time as the user rotated or moved the mobile device. When the field demonstration was done in late 2018 and early 2019, important attributes such as striping color, sign size, and draining box dimensions from the 3D design model were not yet available on mobile devices with the vendor's AR app. Even without the attributes, crews commented on the value and were excited at the prospect of using AR with 3D design model attributes included.

With an improved tool, UDOT expects to test out AR use again on a project in summer 2020. UDOT anticipates that most, if not all, of the 3D design model attributes will be included in the AR app.

For UDOT, the most valuable use for AR will probably be for underground utilities during design, construction, and asset management and operations. Although UDOT anticipates AR to be useful and valuable, there will be short-term gaps with most, if not all, information in 3D design models. Until a fully geospatial utility database is populated, the geospatial location of angle points, valves, and other details often will not be known during the design phase of the project.

UDOT is currently working toward populating a utility database. One benefit of such technologies is that they can lead to the proper recording of utility placement during construction. Once the utilities are observed in the field by AR devices, their locations and attributes are recorded as digital as-builts for future applications.

"Although it may take a significant amount of time to populate an underground utility database, the potential for substantial reduction or elimination of delays due to utility conflict is impressive," says Lukes. "AR will undoubtedly increase construction efficiency with accurate representations of the underground utilities."

FDOT's AR Modeling

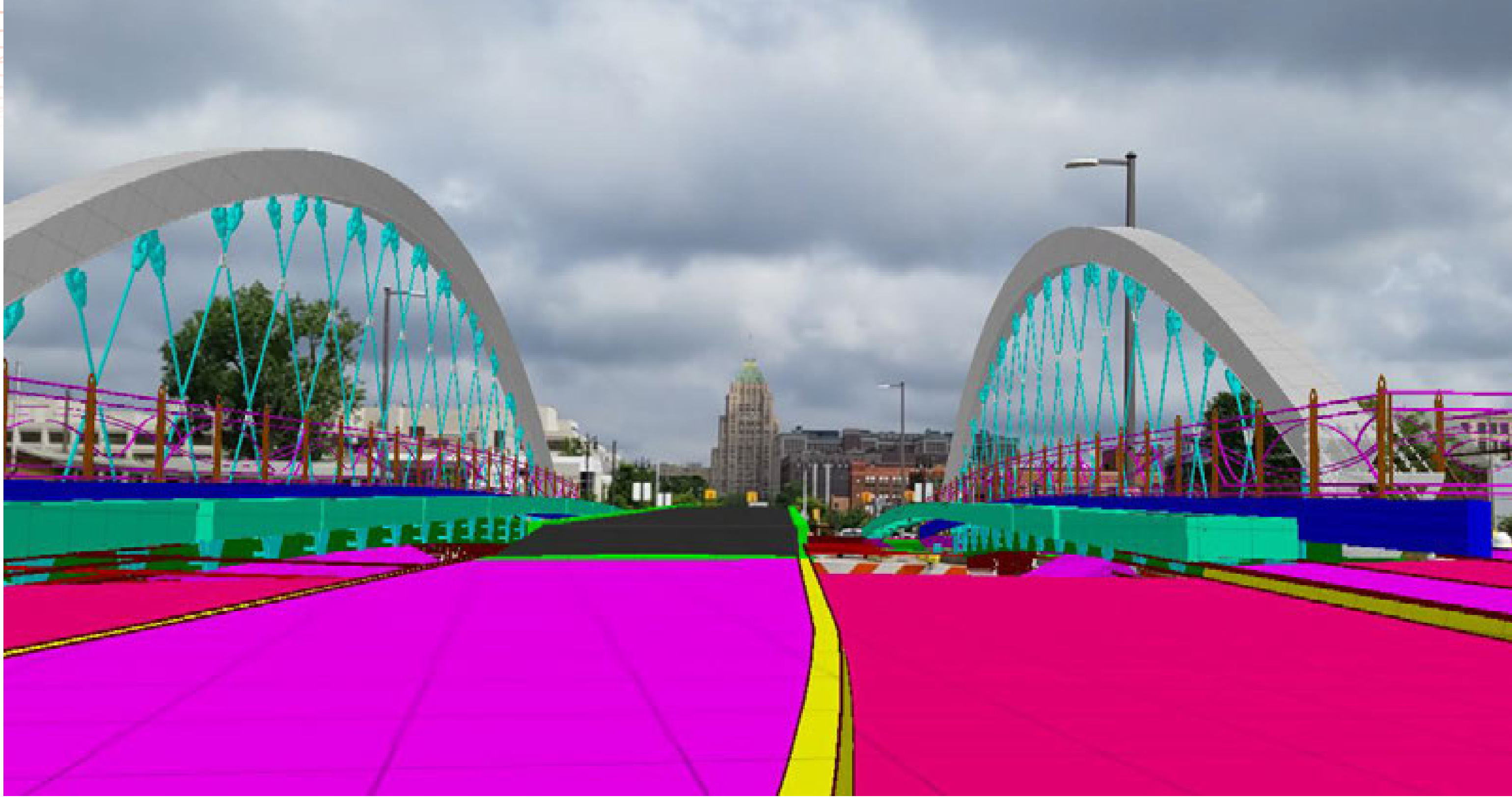
In Florida, AR is reshaping the how District Five of the Florida Department of Transportation (FDOT) delivers projects. The agency uses the technology in almost every aspect of a project. Starting in the design phase, District Five is using AR to review 3D design models. The AR technology not only enables designers to identify errors, it also helps them to easily identify constructability issues with a design.

For example, designers have used AR to identify conflicts between drainage structures and existing utilities. While these conflicts can be seen in a computer-aided design and drafting environment, constructability of the inlet is not always as obvious. Nearby utility poles or other hard features can sometimes impact the constructability of the drainage structures. AR makes these conflicts easily visible.

FDOT also uses AR technology to review and visualize a model and get feedback from stakeholders in the design phase. Instead of the stakeholders reviewing a project on a 2D sheet of paper, they are able to view an AR model in the field. This visual overlay results in a faster review and a better overall understanding of the project.

FDOT is moving into its first construction project using AR. The team is using automated machine guidance to construct a majority of the elements. The project has no plan sheets and instead has a signed and sealed 3D model as the contract document. This puts additional emphasis on the model compared to other projects. AR will enable crews to quickly check constructed elements against the proposed model. The AR technology will also enable contractors to review form work before concrete is poured. Any element that needs to be laid out during construction can be quickly checked against the proposed model with AR technology.

AR devices can provide a 3D virtual view of underground utilities, such as this manhole access point and the surrounding piping, as well as text with associated data.

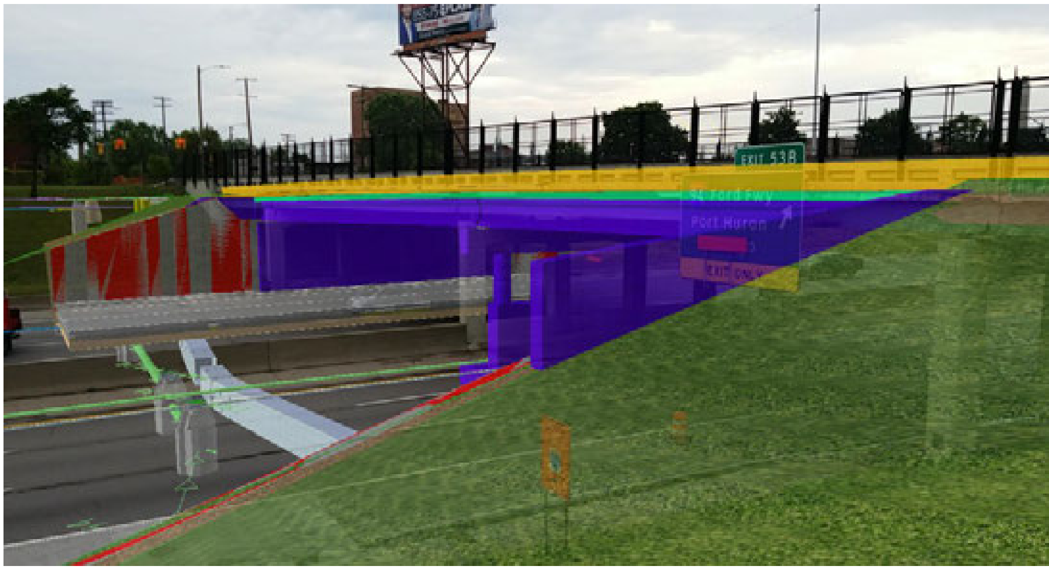


After construction, the benefits of AR continue. FDOT's maintenance offices will be able to use the 3D as-built record for future maintenance and rehabilitation with a high degree of accuracy.

Michigan and California

Other States are using AR technologies to improve their processes and outcomes as well.

The Michigan Department of Transportation used AR technologies for visualization of bridge replacements on the I–94 Advanced Bridges Project in downtown Detroit. The ability to visualize the new bridge design over the existing aging bridge, including abutments and structural details, enabled the project team to review proposed design elements overlaid on reality. This provided the designers with unique perspectives and contextual placement of their 3D designs. Future applications of AR technology could include verifying that existing 3D models containing underground utilities are accurate, visualizing potential conflicts between the proposed design and existing facilities, and communicating the proposed design to affected project stakeholders.



TOP: Michigan DOT tapped into AR to help visualize proposed design changes for the Second Avenue Bridge to share with the public and stakeholders.

CENTER: AR is proving beneficial to engineers in helping to locate underground utilities, enabling designers to verify location accuracy for its 3D modeling.

BOTTOM: Engineers used AR to propose design elements, overlaying the elements onto existing conditions on the bridge carrying Milwaukee Avenue over I-75.

© HNTB.

In Sacramento, CA, a recent construction manager/general contractor study of new bridge construction incorporated AR technologies. The team could review the 3D model in the office and then use the AR model onsite for visualization of bridge pilings, right-of-way, and structure components, as well as clearly identify an underground high pressure jet fuel line that ran parallel to the new bridge.

FHWA Research Findings

AR hardware, software, and applications are rapidly changing and improving. The findings of the FHWA research study of current technologies, opportunities, and challenges all point to potential future directions for AR use in highway construction. However, future applications will require investment in specific hardware and software frameworks. The FHWA study identified the following top five potential applications in terms of possible impact on transportation construction and feasibility of development:

1. Supporting right-of-way acquisition and providing project visualization to property owners to better understand project impacts and design options.

2. Visually annotating the schedule and quality variances in the field to ensure that all parties view the same issues.

3. Verifying proper installation by providing the right information and format for inspectors in the field.

4. Supporting training and certification for construction inspection.

5. Supporting automated compliance checks of codes and standards for installed items through machine learning.

These identified potential applications can serve as starting points for transportation agencies and developers to focus their AR development and implementation efforts in the near- and long-term future. The most important requirements for each application are the software development; the coordination of hardware as an integrated working solution; and the application for the user interface, data input and output, and 3D model management. The application and hardware should be seamless so that the users can focus on the tasks they need to accomplish.

The lack of information on return on investment to justify AR implementation is a challenge. This is a traditional barrier to new technologies; however, independent field trials have helped address the concern and further the development and implementation of the technologies. Multiple objective field trials that examine the benefits and costs of AR based on empirical results will further alleviate this obstacle.

"Just as innovations in automated machine guidance, inspection, and quality assurance using unmanned aerial systems are changing highway construction for the better, advancements in AR technologies offer the potential to facilitate construction inspection processes," says Hari Kalla, FHWA's Associate Administrator for Infrastructure. "Innovations such as 3D-model-based workflows that are being advanced through FHWA's Every Day Counts initiative will provide opportunities for using AR on highway construction projects in the future."

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

KEVIN GILSON is the director of design visualization in the project visualization group with an international transportation consultancy firm. He oversees visualization production, technology development and innovation, implementation of building information modeling, and 3D-model-based design processes within the firm. He holds an M.A. in design from the University of California, Berkeley.

For more information, contact Hoda Azari at *Hoda.Azari@dot.gov*.

A screen shot from the display of an AR headset shows the 3D wireframe view of surface data captured by sensors on the device and superimposed over a video view of the existing site. The overlaid numbers show the size of the area being scanned, 17.769 square meters (191.26 square feet).

Screenshot © Los Alamos National Laboratory.

AR headset photo © Dekdoyjaidee / iStockphoto.

CARMA℠: ENABLING COLLABORATION and ENSURING SAFETY in FREIGHT OPERATIONS

FHWA-created CARMA℠ software supports the testing and advancement of automated driving systems in the commercial trucking industry.

FHWA's CARMA program has equipped four commercial motor vehicles to study connected vehicles and automated vehicle technology applications in freight.

Source: FHWA.

by **HYUNGJUN PARK, NICOLE MICHEL,** and **KIRK CLAUSSEN**

The primary mission of the U.S. Department of Transportation's Federal Motor Carrier Safety Administration (FMCSA) is to reduce crashes, injuries, and fatalities involving large trucks and buses. In 2019, there were 128,739 crashes involving large trucks and buses, which caused 3,543 fatalities and 68,851 injuries. Cooperative driving automation (CDA) has the potential to increase the safety of the Nation's roadways and achieve USDOT's vision of safer roads and zero fatalities.

In a joint project, the Federal Highway Administration, FMCSA, U.S. Maritime Administration (MARAD), and USDOT's Intelligent Transportation Systems Joint Program Office (ITS JPO) are using CARMA℠ software to develop CDA systems that can improve the transportation efficiency and safety of commercial motor vehicles (CMVs). CDA equips vehicles with the ability to communicate with other vehicles, infrastructure, pedestrians, cyclists, and other road users.

Composed of the CARMA Platform℠ and CARMA Cloud℠, CARMA is an open-source software created by FHWA that enables researchers and engineers to develop and test CDA features on properly equipped vehicles across different travel scenarios. The CARMA Platform provides cooperative research functionality to an automated driving system (ADS) and, in tandem with the real-time traffic and weather information provided by CARMA Cloud, enables automated vehicles to interact and cooperate with other vehicles and infrastructure.

"The CARMA ecosystem was architected with a flexible framework to advance emerging automated driving technology that will enable CDA," says Taylor Lochrane, a technical program manager in FHWA's Office of Operations Research and Development. "The framework enables seamless integration with diverse vehicle models ranging from passenger cars to heavy trucks."

The latest version of CARMA is publicly available on the GitHub development platform at *https://github.com/usdot-fhwa-stol/CARMAPlatform*.

Freight and Research Focus

FMCSA's Automated CMV Evaluation program focuses on research, development, and testing of CARMA-equipped commercial trucks, as documented in the agency's Automated Truck Safety Research Plan.

CARMA-equipped freight vehicles navigate the roads around FHWA's Turner-Fairbank Highway Research Center.
Source: FHWA.

FMCSA is currently expanding its knowledge base in the areas of automated CMV inspections, operation of automated CMVs in and around work zone areas, and considerations for emergency response personnel when interacting with automated CMVs. FMCSA's program supports the safe and timely deployment and operation of automated CMVs, expanding the knowledge base for automated CMV safety, and updating inspection and enforcement practices for automated CMVs.

MARAD, in conjunction with ITS JPO research programs, seeks to increase cargo capacity and reliability of freight moving through ports. MARAD is engaged in a multiyear research program that seeks to achieve two primary goals: 1) to identify opportunities to conduct research that addresses critical freight movement and ITS infrastructure gaps; and 2) to identify opportunities for pilot projects and programs to be deployed including technology transfer. The goal of the program is to use ITS to improve the performance of maritime ports and terminals along with the larger freight network, including to increase efficiencies and safety and decrease emissions.

CARMA equips vehicles with the ability to interact and cooperate with other vehicles and roadway infrastructure, which could facilitate freight operations by increasing cargo capacity and the reliability of freight movement through ports. FHWA, FMCSA, MARAD, and ITS JPO are conducting research using a fleet of four CARMA-equipped heavy trucks to demonstrate the benefits of connected and automated vehicle technology for loading and unloading chassis and containers, passage through inspection points and gates, and short-haul drayage.

The CARMA freight research builds upon and extends research from CARMA Platform, CARMA Cloud, and CARMA simulation projects to support use cases for ADS transportation systems management and operations. The project will also provide recommendations for cybersecurity research areas, as related to CMVs, to expand the freight research framework found in FMCSA's Automated Truck Safety Research Plan.

Proof-of-Concept Testing

In spring 2021 at the U.S. Army's Aberdeen Test Center in Aberdeen Proving Ground, MD, research teams will conduct a proof-of-concept use case application developed using agile Scrum methodology to demonstrate the ability to increase freight movement at ports through CDA interactions with port infrastructure. The CARMA automation will be limited to the forward motion of the trucks, and simulated operations will involve moving payloads on and off a single attached chassis.

The proof-of-concept testing will integrate cooperative ADS capabilities with freight mobility strategies, first on closed test tracks and then on public roads to evaluate cooperative automation for port management. In one testing scenario, heavy vehicles may be set on a route to navigate from a starting point lot to a location for loading and unloading chassis and containers. Vehicles will stop at an inspection point, and those that pass inspection will continue onward while those that fail inspection will navigate to a holding area for further assessment. Vehicles will subsequently navigate gate passage, emulate a short-haul drayage, return to the starting location, and reverse or loop around into a loading and unloading area at the starting point lot. CARMA Cloud may be used to manage the rules of the fleet as the ADS-enabled heavy trucks progress through each activity.

Looking Ahead

A multiyear project, the FHWA CARMA freight initiative is performing critical CDA research in phases on automated port operations and automated CMV operations. Studies will demonstrate the role of ADS in increasing efficiencies and safety, while decreasing emissions, in a port environment. The research aims to advance technology

implementation in the Nation's ports and investigate a positive cost-to-benefit ratio for automated truck movement and port operations.

The CARMA architecture is designed for easy sharing and integration into different vehicle categories, supporting research and testing on ADS in CMVs. CARMA-enabled trucks introduce new avenues for innovation by expanding data collection opportunities and enabling shared expertise and pilot transportation technologies. CARMA truck programs seek to identify opportunities to conduct research that addresses gaps in freight movement, intelligent transportation systems infrastructure, and commercial vehicle safety.

"Through this critical research, USDOT hopes to harness CDA concepts in order to reduce large truck crashes and enhance freight mobility," says Kevin Dopart, a program manager in USDOT's ITS JPO. "We are working toward the ultimate goal of transforming the transportation industry."

HYUNGJUN PARK is a highway research engineer in FHWA's Office of Operations Research and Development, managing various CDA activities focusing on commercial motor vehicles and freight. He earned a B.S. in city planning from Hanyang University in Seoul, South Korea, and an M.S. and a Ph.D. in civil engineering from the University of Virginia.

NICOLE MICHEL is a mathematical statistician in the Research Division of FMCSA's Office of Analysis, Research, and Technology. She manages a variety of contracts and projects to enhance FMCSA's missions to reduce crashes, injuries, and fatalities involving large trucks and buses. She earned a B.S. in mathematics from Loyola College in Baltimore, MD; an M.S. in statistics and finance from Towson University in Towson, MD; and an M.S. in engineering systems from the Naval Postgraduate School in Monterey, CA.

KIRK CLAUSSEN serves in the MARAD Office of Ports & Waterways, providing guidance to ports on infrastructure investment, including for ITS. He leads the ITS program with a focus on planning, funding, and deployment of technology solutions to increase cargo capacity and reliability of freight moving through ports.

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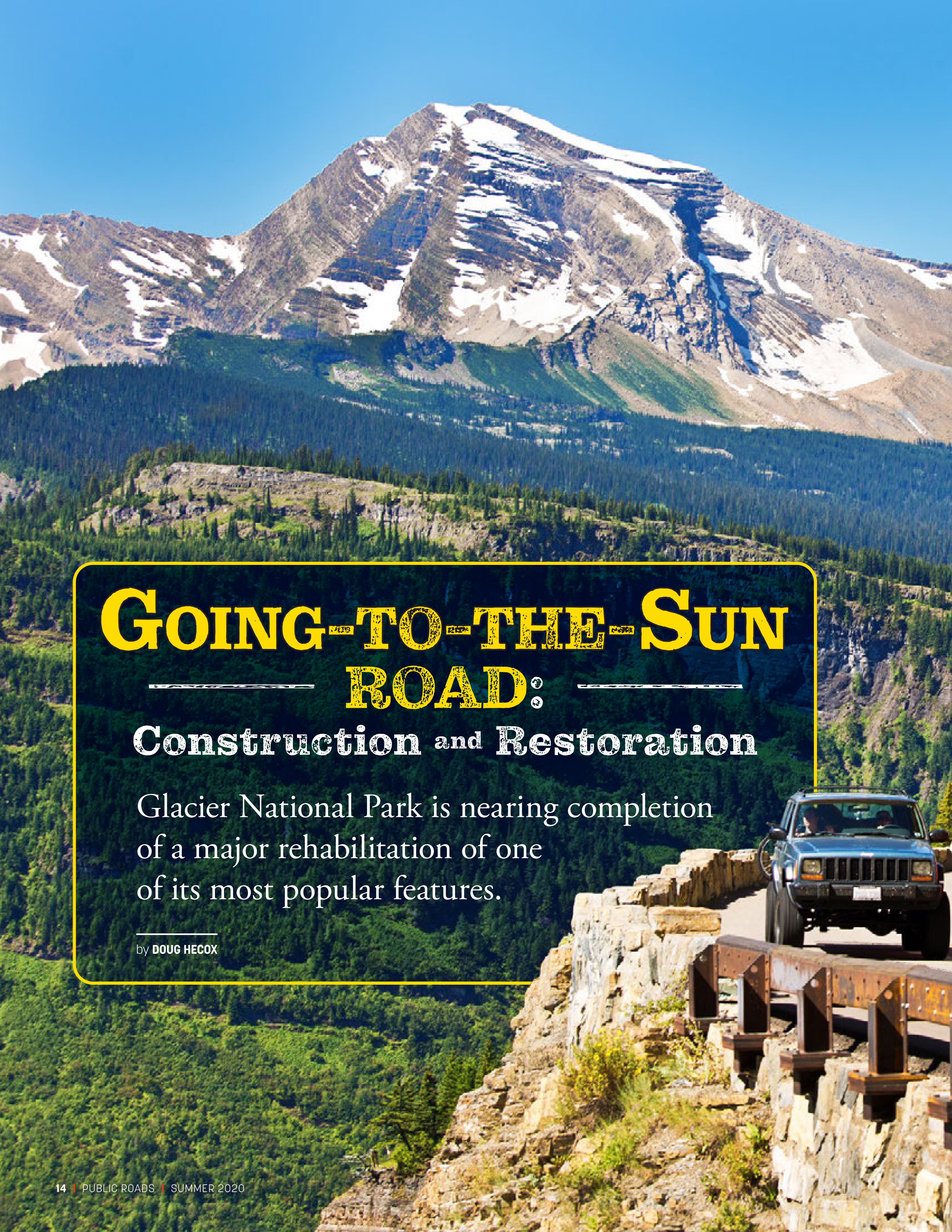
CARMA equips vehicles with the ability to interact and cooperate with other vehicles and roadway infrastructure.

Source: FHWA.



Going-to-the-Sun Road:

Construction and Restoration

Glacier National Park is nearing completion of a major rehabilitation of one of its most popular features.

by **DOUG HECOX**

Travelers encounter many spectacular views as they traverse Going-to-the-Sun Road in Montana's Glacier National Park.
© YinYang / iStockphoto.

Going-to-the-Sun Road in Montana's Glacier National Park attracts millions of visitors each year to enjoy a drive through its beautiful scenery of lakes, streams, mountains, and facilities. Established as the tenth park in the Nation on May 11, 1910, Glacier National Park covers more than 1 million acres (400,000 hectares), including 175 mountains and 26 glaciers, with the Continental Divide essentially cutting the park in half. The 50-mile (80-kilometer) Going-to-the-Sun Road runs along and over these steep mountains. The elevation at Logan Pass, located in the midsection of the road and the highest point accessible by car, reaches 6,646 feet (2,026 meters).

"The road is not just a way to travel, it's a destination in itself," says Michael Traffalis, a project manager in the Federal Highway Administration's Western Federal Lands Division.

Its construction was a marvel of design and engineering in the face of unique challenges. Rustic stone masonry features include bridges, drainage structures, and horse underpasses. These significant features have led to Going-to-the-Sun Road being recognized as a Civil Engineering Landmark in the National Historic Register and as a National Historic Landmark.

However, decades of rockslides and avalanches, severe weather, and heavy traffic left the road in urgent need of repair. Without aggressive action, the historic structures for which the road is so admired might have been lost. In 2007, the National Park Service (NPS) and FHWA embarked on a monumental rehabilitation project, which is now coming to a close.

Collaborative Planning and Construction

The construction of Going-to-the-Sun Road launched a national cooperative agreement between the NPS and the Bureau of Public Roads (a predecessor of FHWA). At the time, it was the largest construction project ever undertaken by the two agencies.

In 1918, George Goodwin, the first NPS engineer, planned a route that became the guideline for the initial transmountain road construction in the early 1920s. Goodwin's proposal was similar to the current road, except that it would have made a steep climb up Logan Creek using 15 switchbacks before reaching the Continental Divide at Logan Pass. A later adjustment, suggested by NPS landscape architect Tom Vint, adopted an alternate approach requiring only a single switchback.

During the early 1920s, Congress provided annual appropriations of $100,000 for construction of the road. With this money, the park signed contracts to begin construction at both ends of the road. In 1924, Glacier's appropriation increased to $1 million for a 3-year road construction program.

Frank A. Kittredge of the Bureau of Public Roads directed a 1924 survey for the road. The project, which mapped out 21 miles (34 kilometers) over the Continental Divide, started in September, and Kittredge raced to finish the survey before winter weather ended activity. He and his team of 32 men often climbed 3,000 feet (914 meters) each morning to get to survey sites. The crew walked along narrow ledges and used ropes to suspend themselves over cliffs to take many of the measurements. The work was too challenging for some, and Kittredge's team suffered from a 300 percent labor turnover in the 3-month work period.

The road was an early example of context sensitive design. While the Bureau of Public Roads provided road-building expertise, NPS landscape architects, together with the Bureau's engineers, created the specifications for the road, working to blend it into the surrounding environment. The landscape architects required that the bridges, retaining walls, and guardrails be made of native materials. The engineers ensured that the integrity of the road and construction practices met the required safety standards of the time. Most of the structures along the road consisted of rock excavated from the adjacent mountainsides during construction. Contractors had to use numerous small blasts of explosives because large blasts would cause more destruction of the landscape. However, despite the architects' recommendation to exclude the use of power shovels, workers employed them because the expense of a road built exclusively with hand labor was too great.

The engineers, landscape architects, and laborers faced sheer cliffs, short construction seasons, snow, and removal of tons of rock to open the road. After more than 12 years of engineering and construction, the first automobile traversed the full 50-mile (80-kilometer) roadway in late 1932. The NPS officially opened the road in a dedication ceremony on July 15, 1933, and named it Going-to-the-Sun Road. It has endured since as one of the park's most popular features.

Reconstruction and Rehabilitation

By the mid-1990s, the NPS and FHWA worried that the road's structural integrity was in such disrepair that the road might have to be closed to visitor traffic. This led to a rigorous planning effort, starting with a $1 million appropriation for studies and reports that led to the alternatives outlined in the Going-to-the-Sun Road environmental impact statement, completed in 2003. An advisory committee recommended a shared-use approach to reconstructing the road with short weekly delays, shoulder season closures, and a visitor bus shuttle service.

Project planners estimated that rehabilitation work would take 7 to 8 years, pending funding. FHWA estimated the cost of the decision, including economic and visitor access mitigation, to be between $140 and $170 million.

Even for modern road crews and equipment, Going-to-the-Sun Road presents challenges. Here, crews must dangle over the edge to repair the stone wall along part of the roadway. When the road was built, the task was so difficult that many workers quit.

Source: NPS.

During months when the park was open to visitors, FHWA and NPS had to plan the road work to enable access, such as for this park shuttle.

Source: NPS.

As a first step, the NPS and FHWA's Western Federal Lands Highway Division jointly developed and implemented the Glacier National Park shuttle system in the summer of 2007. This shuttle bus system provided alternative transportation access and maintained capacity to accommodate visitors during reconstruction. The system continues to provide a means to reach Logan Pass.

Construction Strategies

The project implemented a number of strategies to minimize the impact to park visitors and reduce costs. Strategies used to improve building efficiencies included more night work when the NPS could implement long public road closures. Engineers worked with contractors to modify or adjust details to increase effectiveness for weather conditions, adjusting seasonal construction limits to match production rates to maximize work days.

One of the major cost-reducing strategies concentrated existing funds on the alpine section, the area in most need of repair. In contrast, the lower sections were subject to less extreme weather and experienced less freeze-thaw damage, so their masonry features were in better shape and the pavement in better condition.

To minimize gaps in construction time, crews moved from high elevations to low elevations based on weather factors. Spring construction work was done at lower elevations. The overall construction season stretched from April 1 to December 15, but work at higher altitudes took place from mid-June to mid-September when weather was not such a limiting factor. One complication was that these months account for the heaviest concentration of visitors, so the roadway had to remain accessible for tourists.

Overcoming Challenges

Construction began in 2007 and was substantially completed in 2019, with a few final efforts remaining, including masonry repair, vista clearing, staging area management, and construction of guardrails in isolated spots. The NPS and FHWA anticipate completing these final projects this fall.

The extensive project faced myriad challenges. In addition to the difficulties presented by the weather and the geography, these included maintaining shared use—limiting traffic delays to 30 minutes, accelerating shoulder season work, providing transit service during rehabilitation, and improving visitor use—by providing visitor orientation, information, and interpretation. The planners also needed to minimize effects on natural, cultural, and scenic resources; minimize impacts on local and regional economies; and limit the management of vegetation, all while completing the work within the planned timeframe and managing funding levels.

"The most important objectives were minimizing economic impacts, getting the transit system up and running, and maintaining visitation," says Traffalis.

Adjusting to Weather Conditions

The high alpine section had a tight weather window. Logan Pass can receive an annual accumulation of up to 80 feet (24 meters) of snow in the winter, and snow often continues into the summer months.

Especially in the highest elevations, the weather presented a constant challenge to the rehabilitation project. The presence of wildlife, like the bear that left these tracks, can also be a complicating factor.

Source: FHWA.

Construction crews used a combination of heavy and light equipment, as well as handwork where needed, because of the geographic and physical limitations presented by the roads and tunnels.

Source: NPS.

Construction relied heavily on the shoulder seasons, between the visitor peak of summer and the inaccessibility of winter, when the park closes its gates for snow plowing in the spring or winter preparations before the snow. This enabled construction to take place without public traffic. Snow runoff in the spring made construction difficult. Culverts plugged up with ice during the winter, resulting in water sheeting down the shoulder of the road and flowing over historic masonry rock walls, causing damage and making erosion control critical. As part of the rehabilitation project, crews constructed a series of gutters to direct the runoff flow to designated areas to avoid erosion.

The water flow also made paving in the spring difficult due to high water levels and runoff on the road. The surface had to be dry in order to pave, so the engineers typically had to wait until fall to pave. The road also had to be drivable between mid-June and July, so the construction was phased to have at least a temporary hardened roadway surface in place by winter shutdown. The park needed this temporary surface to enable both spring snow plowing and anticipated summer traffic. These weather considerations combined with a significant drop in tourists after Labor Day created a short window in the fall before October snows arrived to pave the alpine section.

Geographical Challenges

The limited width of the road made it difficult to move visitor traffic around construction equipment. Some areas were only 8 feet wide. Tunnels with restricted height clearance, such as Half Tunnel, meant that dump trucks could not completely lift to unload materials. Paving required a lot of handwork throughout the alpine section. In this area, paving had to be done up against guard walls and the exposed rock wall face.

On numerous occasions, ice and rock falls damaged construction equipment, workers' personal vehicles, and government vehicles. Unstable slopes and rockfall above the roadway required limiting rollers to no vibratory compaction of the road surface for the safety of the workers and public.

Rockfall mitigation work required completing a rockfall hazard rating system inventory along the entire roadway. The work included inventorying and rating rockfall-prone slopes to prioritize mitigation efforts. Engineers selected high-rated slopes for risk reduction and mitigation methods with minimal visual impacts. These methods involved slope scaling within 50 feet (15 meters) of the roadway, rock bolts with anchorage assemblies (bearing plates) removed, and sections of colored and textured shotcrete. The coloring and texturing preserved the historic appearance of the road.

The project used rock bolt reinforcement, the insertion of steel rods to provide support to a rock face, when scaling was not an option, usually when encountering large

Snow accumulation along Going-to-the-Sun Road, and the resulting snowmelt in the spring, limited the available windows for construction and paving.

Source: NPS.

Crews had to mitigate rockfall risks and support rock faces along the road while maintaining the natural look of the surrounding area.

Source: NPS.

stone formations. The bolts were driven deep into the rock—15 feet (4.5 meters) or more—tensioned, then grouted solid. Engineers recessed the surface cover plates and covered them with colored masonry to match adjacent rock.

Assessing and Repairing Damage

The rehabilitation and reconstruction project included permanent repairs for areas of the road that had temporary measures installed in the past, as well as wear-and-tear damage from heavy use.

In 2006, Glacier National Park saw one of the heaviest November precipitation events on record. The storm dropped approximately 11 inches (28 centimeters) of rain on top of 8 inches (20 centimeters) of snow over a short period, causing severe erosion of the slopes and six major failure locations. The storm washed out 120 feet (37 meters) of road, and FHWA used mechanically stabilized earth walls along with a temporary bridge to span one large erosional ravine along Going-to-the-Sun Road.

To permanently repair the damage, the reconstruction project installed stone masonry consisting of 582 square yards (487 square meters) of veneer, 1,233 linear feet (376 meters) of ashlar, and 574 square feet (53 square meters) of random rubble. Engineers reinforced a stone masonry wall, showing signs of instability and located where access was prohibitive, using micropiles. The crew installed the micropiles down through the existing stone masonry wall and into the underlying bedrock. The cap stones were replaced following construction to conceal the repairs.

The outboard lanes—those nearest the outer edge of the road—showed signs of fill slope settlement failures. The reconstruction stabilized the fill slope shoulders by placing flexible geogrid and select rock material in lifts under the surface. Pressure grouting stabilized the outside lanes, combined with underdrains, improved ditching, and culvert replacements. The project used a total of 6,900 cubic yards (5300 cubic meters) of riprap in some areas for slope repair.

The bridges and tunnels of Going-to-the-Sun Road are subject to extreme weather conditions. Over their service life, they have all experienced extensive freeze-thaw damage to exposed edges of the bridges and portals of the tunnels. The assessment team found additional deterioration in the stone masonry railing and piers, widths not meeting current standards, poor conveyance of stream hydraulics, porous concrete, and rising stream bed loads. Stream beds rise due to glacial melt, which releases thousands of years of rock frozen within—a challenge throughout the entire Northwest.

Along most of Going-to-the-Sun Road, existing rails and border walls needed repair. Here, a worker inspects a completed section of wall.

Source: FHWA.

The work teams replaced all of the old guardrail, shown in this undated historic image, with removable steel-back timber guardrail.

Source: Library of Congress, Prints & Photographs Division, Historic American Engineering Record, HAER MONT, 15-WEGLA, 5–80.

As streambeds rise, the hydraulic capacity of existing culverts and bridges is negatively affected.

All of the bridges and tunnels included historic features. Following the NPS mission of preserving and protecting structures, engineers were charged with restoring the bridges in lieu of complete replacements. To accomplish this task, the NPS and FHWA partnered with cultural and historic preservationists, landscape architects, materials-testing firms, contractors, and resource biologists to develop custom solutions for each structure.

These activities required fully assessing and documenting existing conditions, evaluating those elements of the bridge that were still contributing (historic) features, and then undertaking strategies of restoration to remove and replace freeze/thaw-damaged concrete, reseal porous concrete, repair masonry, and clean channels. Teams cleaned each masonry face using relatively low-pressure washing and scrubbing with nylon brushes to expose the masonry and its grouted joints.

Innovating for Sustainability and Preservation

The project implemented several innovations to preserve the original features wherever possible and to minimize costs and labor.

In particular, the project reused existing asphalt concrete pavement in the structural pavement layers of the repaved roadway. The recycled asphalt pavement (RAP) was used throughout Going-to-the-Sun Road in two different forms. The first served as a direct one-to-one replacement for the aggregate base layer. This material was easier to maintain under traffic because it reduced dust and it required less maintenance and rework.

For the second recycling method, the RAP was hauled from the project, mixed with an engineered emulsion, and brought back to the construction site as a cold recycled asphalt base. This process reduced emissions because no hot plant was used, only a pugmill with emulsion and water injected into the material. The cold recycled asphalt became a structural layer placed directly below the alpine concrete pavement. The RAP mixture is twice as strong as an aggregate base layer and provided an opportunity to use sustainable materials, reduce the need to produce virgin materials to use on the project, use existing materials that were already within the project limits, save time and money, and reduce the carbon footprint inherent in using traditional methods. The use of RAP enabled Glacier National Park to lead the recycling efforts applied by the NPS.

In addition to recycling material, significant efforts went into assessing existing guard walls and guardrails to preserve as much of the original work as possible. For the areas where repair was unavoidable, only minor structural work, underpinning, and repointing were needed. When replacement was the only option, project engineers used a combination of rebuilding the masonry rails or replacing them with log railings or avalanche-resistant masonry rail.

These techniques alone could not solve the problem of yearly avalanche damage that would continue to occur. To address the issue, the NPS and FHWA developed a removable, crash-tested, log-guardrail system. These removable log rail sections have been installed within defined avalanche zones. The sections are taken out at the end of the tourist season and reinstalled the following year.

“This innovative feature prevents costly avalanche damage to the guardrails and ends the cycle of yearly replacement costs to sections of the roadway damaged by avalanches,” says Traffalis.

Project Successes

At a cost of more than $160 million, the completed road reconstruction, rehabilitation, and repair project that began in 2007 has been largely completed. The work included retaining walls, arches, bridges, and tunnels; guard walls and removable guardrails; other roadside improvements; drainage; slope stability; pavement; transit system (buses, transit stops, and transit center) enhancements; and two new visitor center entrance stations.

Visitor improvements at pullouts included upgrading trails for accessibility and several construction upgrades to view points. Additional viewing areas were enhanced with "crow's nests" to give visitors a true immersive experience. Turnouts were equipped with new interpretive panels, and the Sun Point visitor area adopted new interpretive messaging.

Other than the addition of the transit stops for the park shuttle operation, project engineers and architects ensured that the roadway would retain its important and inherent historic character through attention to fine details, such as using materials to match the historic character of the original road. The materials were salvaged from repair and construction segments, gleaned from roadside salvaging and sealing, or quarried and shaped from outside sources.

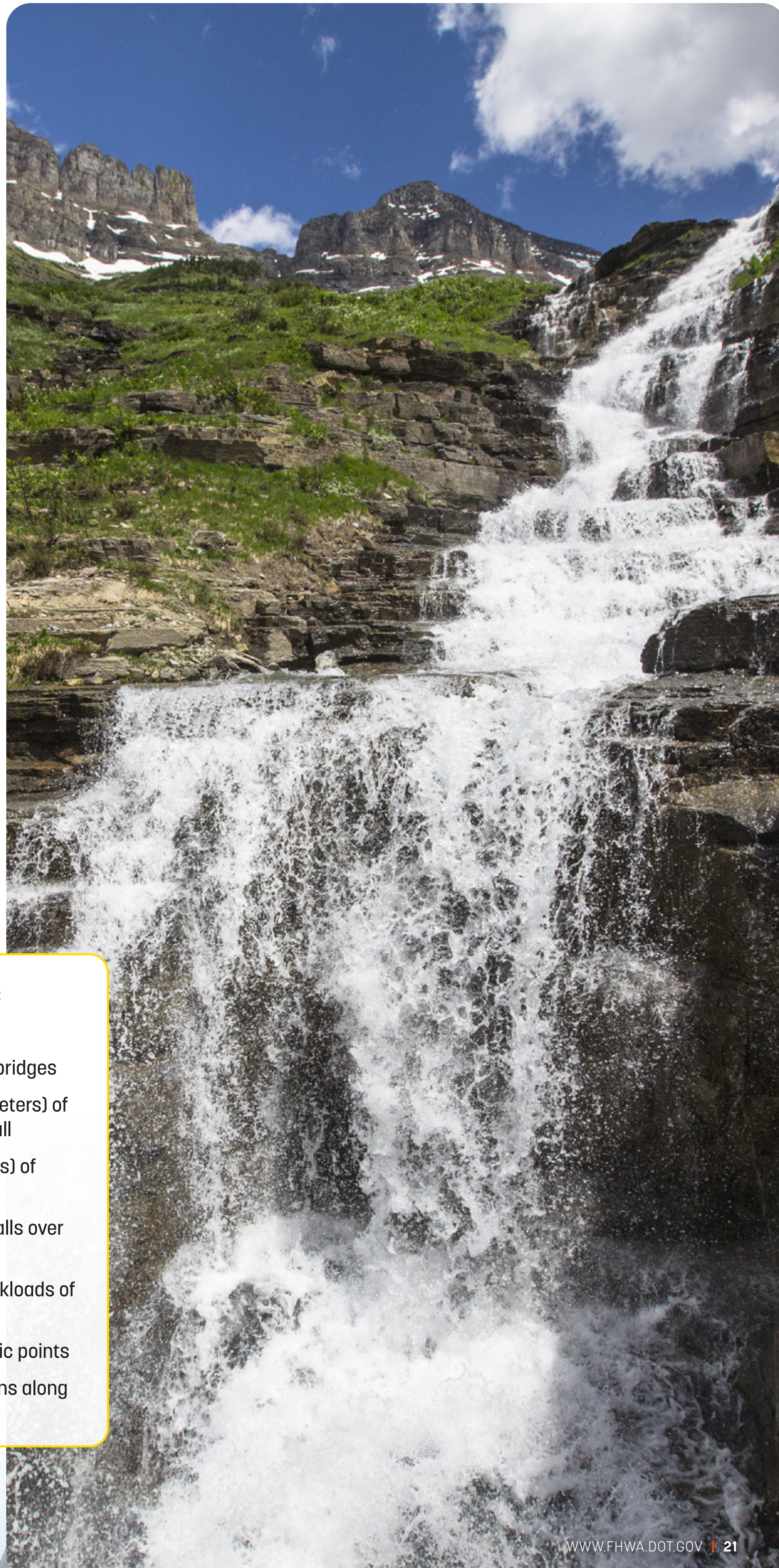
The investment into Going-to-the-Sun Road is nearly complete, with one remaining cleanup contract scheduled for this summer to repair any features that sustained wear and tear since the rehabilitation began. The NPS and FHWA can now welcome the hundreds of thousands of visitors that Glacier National Park receives per month during the open season.

"Today, Going-to-the-Sun Road is in better repair than ever before," says Traffalis, "Ushering in the next 100 years of the NPS opening its doors to visitors from all over the world."

DOUG HECOX is the senior career spokesman with FHWA's Office of Public Affairs. He has a journalism degree from the University of Wyoming, has published two books, and teaches journalism and public relations writing at American University.

Major accomplishments include:

- Replacing the Rose Creek Bridge
- Rehabilitating 2 historic tunnels and 19 bridges
- Constructing more than 2 miles (3 kilometers) of new random rubble and ashlar guard wall
- Installing more than a mile (1.6 kilometers) of steel-backed removable guardrail
- Repointing and repairing hundreds of walls over the entire road
- Hauling in and out more than 2,000 truckloads of material
- Providing eight accessible trails to scenic points
- Constructing 14 transit stops and stations along the roadway



Thanks to the massive rehabilitation project, views like these will soon be much more accessible to park visitors.

Source: NPS.

FHWA's SBIR Program helps develop market-ready solutions from small businesses to address critical transportation issues.

© deberarr / Getty Images.

EVERYBODY WINS

FHWA's Small Business Innovation Research program is spurring market-ready innovations to address transportation challenges.

by **CRAIG THOR** and **SARAH CIGAS**

As part of its mission to enable and empower the strengthening of a world-class highway system that promotes safety, mobility, and economic growth while enhancing the quality of life of all Americans, the Federal Highway Administration seeks out innovative solutions and technologies to address transportation challenges. However, FHWA often faces difficulties when trying to move potentially innovative solutions from laboratory testing and pilot studies to full market deployment. This challenge to deployment exists across all Federal agencies with large research programs.

In 1982, Congress passed the Small Business Innovation Development Act to encourage the initiative of the private sector and to use small businesses as effectively as possible in meeting Federal research and development objectives. The legislation, which has been reauthorized many times, created the Small Business Innovation Research (SBIR) program. SBIR requires Federal agencies with large research, development, and technology (RD&T) budgets to reserve a portion of those funds for awards to small business, encouraging domestic small businesses to engage in research and development addressing high-priority research areas.

The mission of the SBIR program is to support scientific excellence and technological innovation through the investment of Federal research funds in addressing the Nation's critical priorities to build a strong national economy. FHWA's SBIR program, which is part of the larger U.S. Department of Transportation program, favors research that has the potential for commercialization through products and applications sold to the private sector transportation industry, State departments of transportation, USDOT, or other Federal agencies.

SBIR

Source: USDOT.

SBIR at FHWA

The SBIR program is structured in three phases. The objective of phase I is to establish the technical merit, feasibility, and commercial potential of the proposed RD&T efforts. After successful completion of a phase I contract, awardees are eligible to submit a proposal for phase II, which looks to further advance and commercialize the project technologies. Funding for phase II is based on the results achieved in phase I and the scientific and technical merit and commercial potential of the project as proposed for phase II. Furthermore, a phase IIB option is available for particularly promising phase II projects that need additional funding to meet their development or commercialization potential. Although rarely used by FHWA, a phase III contract, which does not include additional Federal funding, may also be awarded to pursue commercialization using objectives resulting from the phase I and II RD&T activities.

Given the specific focus on developing a commercially viable and market-ready product, not all RD&T activities or goals are a good fit under the SBIR program.

"However, in the cases where there is a relevant topic and promising approach from a small business, FHWA has found the SBIR program to be a great option for advancing technologies and making problem-solving innovations available to the end user," says Dr. Kelly Regal, Associate Administrator, FHWA Office of Research, Development, and Technology. "Of course, the small business benefits from the ability to pursue a good idea through Federal seed funding and, if successful, the sale of their innovative products and solutions. This creates a win-win-win opportunity for the Federal Government, the small business, and the traveling public."

FHWA invests in the SBIR program through a set-aside of extramural research funding, including funding provided by the Intelligent Transportation System Joint Program Office. FHWA typically funds two to four new SBIR phase I projects annually covering a range of strategic topics. The topics may be submitted by FHWA staff or the public. FHWA evaluates all topic proposals to identify those that will advance research that supports the USDOT strategic goals and that would be best addressed through a market-ready product. After phase I, which usually lasts about 6 months and offers up to $150,000 in funding, the small business may submit a proposal for a phase II project. A phase II project typically lasts 2 years and can receive up to $1 million in funding. An optional phase IIB may also be funded for another 2 years with up to $1 million in funding.

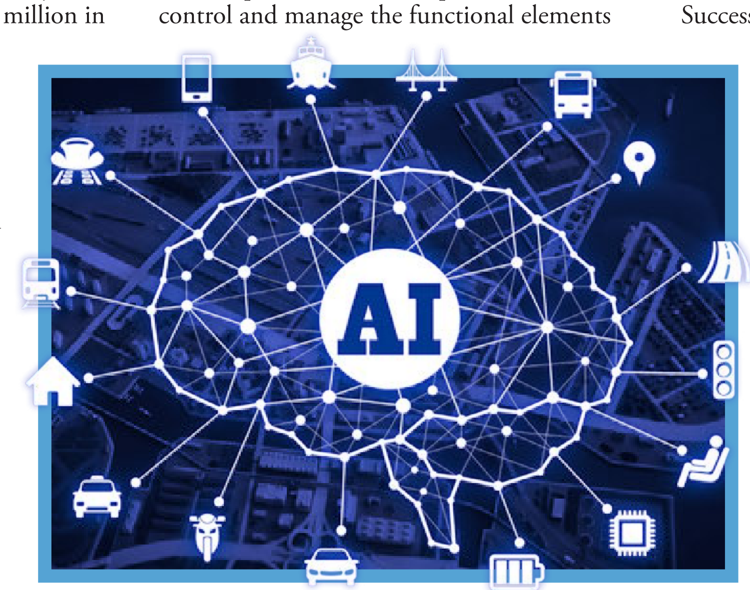
As with all research endeavors, not all paths lead to new innovations. However, the SBIR program can provide a unique opportunity for success. It provides FHWA with a method of investing in specific innovations that can best address a strategic need. Additionally, SBIR gives creative and ambitious small businesses a chance to get a foot in the door and compete in a crowded marketplace. The small businesses also benefit from commercialization consultant services that are offered by the SBIR program, an area in which many small businesses may have very little experience. Finally, the intrinsic motivation of the small business is to produce a market-ready product that can be sold for a future profit. This blend of incentives, services, and opportunity is not typically available through more traditional FHWA RD&T funding approaches.

"Ultimately," says Dr. Regal, "The FHWA SBIR program has proven to be a worthwhile investment with unique advantages for the Government, the small business community, and the traveling public."

Artificial Intelligence in TMCs

A transportation management center (TMC) is the hub or nerve center of most freeway management systems. Traffic and transportation data are collected and processed, fused with other operational and control data, synthesized to produce information, and distributed to stakeholders such as the media, other agencies, and the traveling public.

The role of a TMC often goes beyond the roadway network and the particular responsible agency, functioning as the key technical and institutional hub to bring together the various jurisdictions, modal interests, and service providers to focus on the common goal of optimizing the performance of the entire surface transportation system. Because of a TMC's critical role in the successful operation of a freeway management system—and perhaps the broader surface transportation network—it is essential that the TMC be planned for, designed, commissioned, and maintained to enable operators and other practitioners to control and manage the functional elements of the freeway management system, and possibly beyond.



Advances in artificial intelligence and machine learning offer opportunities to address transportation challenges.

© metamorworks / Getty Images.

While TMCs are critical to the operation of the current driving environment, changes are on the horizon. The introduction of connected and automated vehicles as well as smart sensors will increase the amount of data that are available for TMCs to process. These data will be available on a larger scale and with greater speed than ever before—to the point where humans will not be able to keep up.

However, new advances in artificial intelligence (AI) may present a unique opportunity to address some of these challenges and enhance the efficiency of freeway operations. AI can be used to automate TMC operations and can "learn" to better optimize the flow of traffic. In the near term, this may provide substantial benefits as more connected and automated vehicles and new smart data sources enter the highway environment.

In February 1996, IBM's Deep Blue computer made history when it defeated the reigning world champion, Garry Kasparov, in a game of chess. While others were also working on similar technologies, this demonstrated to the world that computers would soon be able to solve complex and evolving problems at a level that surpassed human capabilities. More recently, Google's AlphaGo beat world-champion Lee Sedol at the game Go, further demonstrating the abilities that computers have to solve increasingly difficult problems and scenarios.

Successes like these inspired FHWA to consider what the possibilities may be for highway applications. Like playing a game of chess or Go, TMCs must respond to changes in the environment and decide what the next move is. Additionally, much like a chess grandmaster, the TMC must look ahead to see what the possible down-field effects of those actions are and analyze a set of possibilities to find the optimal solution.

"The highway environment will make the first 'move,' " says FHWA researcher Dr. Peter Huang, "And it is the role of the TMC to decide what the counter-move will be and predict how the environment will respond with future moves."

For example, if there is a crash on a stretch of interstate, the TMC must decide if vehicles should be routed onto local streets. However, in order to avoid further complications on those roads, a TMC will need to consider whether to make other moves as well, such as adjusting signal timing or ramp metering. Each of these moves has its own corresponding outcomes and tradeoffs, all of which must be analyzed by the TMC. In a traditional TMC environment, digesting this large amount of information in a short period of time to make complex and interdependent decisions can be difficult or impossible. However, as shown by systems such as Deep Blue or AlphaGo, computers—specifically AI and machine learning—present a unique opportunity to find the right move.

Traffic management centers like this one in California are the nerve centers of highway management.
© Peter Beeler, Metropolitan Transportation Commission.

Technology company Intelligent Automation, Inc. (IAI), working with the Delaware Department of Transportation (DelDOT), piloted the Artificial Intelligence Traffic Operations and Management System (AI-TOMS) on a 10-mile (16-kilometer) section of I–95 and surrounding arterials in northern Delaware. The system relies on real-time data from thousands of sensors on the highway and at intersections. Using the existing TMC operations systems, AI-TOMS analyzes the incoming data from vehicle detection radar systems, traffic loop detectors, and other smart infrastructure sensors to make operational recommendations to staff operating the center. Additionally, because AI-TOMS is a learning tool, it tracks the incoming data and resulting operational outcomes to continually enhance its understanding of how the myriad inputs may affect the eventual outcome. Over time, this enables the system to become smarter, resulting in better performance and enhanced safety within the corridor.

The Intersection Dilemma Zone

A second collaborative SBIR effort between IAI and DelDOT also relies on AI, but addresses a challenge at intersections. At the onset of the yellow change interval, drivers must make a decision to proceed through the intersection or decelerate to a stop. The area upstream of the intersection where this decision is made is known as the dilemma zone. In this situation, a vehicle may not have adequate breaking distance to safely stop nor sufficient time to safely traverse through the intersection before the light turns red. The response of drivers within the dilemma zone can contribute to rear-end and side-impact crashes at high-speed intersections.

To address this issue, existing technologies use two approaches: controlling traffic light phases and providing upstream warnings to drivers to prepare to stop. In the first approach, green light phases are extended until sensors determine that no cars are in the dilemma zone. To accomplish this, systems define the dilemma zone as a fixed area on the pavement and assume that any vehicle located in that area at the onset of a yellow light will be faced with the dilemma zone predicament. However, this method uses standard values that may not account for the variation of each vehicle's size, speed, and ability to decelerate. The second approach provides warning signals to drivers, but these signals typically lack direct coordination with the signal controllers.

To provide a more individualized and effective signal control and warning system, IAI developed a technology focused on increasing dilemma zone safety using ITS technology. This system accurately identifies vehicles in the dilemma zone based on the time it would take each vehicle to stop once a yellow light appears. Using sensors, the system identifies each vehicle's size, speed, and location to estimate the time needed to reach the intersection. When the two-part system determines that a vehicle will be trapped in the dilemma zone at the onset of a yellow light, it first uses advanced signal control protocols to adjust interval durations and minimize dilemma zone situations. If vehicles remain in the dilemma zone, the system can alert drivers using an infrastructure warning system, comprised of roadside flashers that are activated based on commands from the detection controller.

Looking toward the future, IAI has also developed an onboard warning system, which uses information from the detection control computer to calculate an individual vehicle's stopping distance and current speed and displays a warning video on a mobile device such as a tablet or smartphone. The warnings notify individual drivers to begin decelerating so there is ample time to stop safely before the intersection. In the future, these systems can be integrated into the vehicle-to-infrastructure communication environment that is being developed by the Federal Government in coordination with State DOTs, private industry, and international partners. Both the infrastructure and onboard warning systems are already integrated into IAI's technology and are ready to be deployed in existing and future market opportunities.

IAI's system has provided promising developments to support FHWA's connected vehicle initiative. FHWA has completed indoor lab testing, outdoor parking lot testing, and testing at the FHWA Turner-Fairbank Highway Research Center. In addition, FHWA conducted human factors studies to confirm the effect of warning systems on driver behavior and safety. Furthermore, because IAI's system is AI-based like the AI-TOMS, it learns over time and will continue to optimize its performance.

Because of the success of both projects with IAI, DelDOT received a $5 million grant through FHWA's Advanced Transportation and Congestion Management Technologies Deployment Program, to which DelDOT is adding $5 million of its own funding for a total investment of $10 million.

"Using these funds, DelDOT plans to deploy these AI technologies, as well as other promising solutions, across the State in an effort to create a truly innovative, next-generation approach to traffic management that uses smart sensors and AI to provide the most efficient and safe operations of our highway network," says Dr. Huang.

Installing Mini-Roundabouts Using Recycled Plastic

Mini-roundabouts, as implied by the name, serve as small-scale versions of the modern roundabout traffic control system that directs vehicles circularly through an intersection. Mini-roundabouts retain the same operating principles to reduce congestion and improve safety, but their small size enables jurisdictions to install them within the footprint of an existing intersection. This eliminates the need to widen roads or relocate utilities. To compensate for their small size, the central islands and splitters are made traversable for trucks and large vehicles that are unable to complete the limited-radius turns.

Vehicles approaching an intersection when the light turns yellow may be faced with the dilemma of braking abruptly or accelerating through the intersection.

© Mike Flippo / Shutterstock.com.

While the benefits of roundabouts are well-known, including increased safety and efficiency, the installation can require the closure of an intersection and the use of permanent materials. Working through the FHWA SBIR program, engineering company ZKxKZ, Inc., identified and developed a design that addresses these issues by providing low-cost, easily-installed mini-roundabouts made from recycled plastic. Whereas conventional methods involve cutting the pavement and filling it with reinforced concrete, this new technology can be installed directly onto existing pavement that is in good condition.

ZKxKZ is using a polyethylene-based composite to take a completely different approach to mini-roundabouts—and potentially other infrastructure installations as well. The material, which is used for railroad ties and is known to be both strong and durable, offers the opportunity to design and precut pieces for assembly at the installation site. Using computer-aided design, ZKxKZ engineers take measurements from geometrical design for an installation site and translate it in a modular mini-roundabout design, which is made up of hundreds of parts that fit together like a jigsaw puzzle.

Using this approach, precut boards can be delivered onsite, ready to be installed. To complete the installation, the precut plastic boards are lined up on the pavement according to the plan's geometric design. The installer then drills through each piece's precut holes and into the pavement, fills the holes with cement, and secures the boards using anchors. This process simplifies the labor and, importantly, does not require the complete closure of the intersection, therefore minimizing the impact on the traveling public.

ZKxKZ's recycled mini-roundabout system has undergone testing to confirm its practicality and functionality at five locations: three installations in Sundre, Canada; one in Jackson, GA; and most recently, in Annandale, VA. The system has shown success in solving critical operational and safety problems. The success of these installations and the future potential for other infrastructure-related improvements, such as channeling curbs and bike lane dividers, led FHWA to invest further into the development of the system through a phase IIB award. Additionally, the United States Air Force identified a number of potential uses to address its priorities as well and is also contributing significant resources through the SBIR program to further realize the potential of this innovation.

Already, this low-cost and easily installed system has demonstrated its ability to address certain traffic and safety issues prevalent on roads. Mini-roundabouts are typically installed to improve safety and traffic flow by forcing vehicles to reduce their speed as they approach the intersection and by doubling the capacity relative to all-way stop control to alleviate congestion. ZKxKZ's system provides a convenient method for demonstrating the effects of mini-roundabouts at particular intersections because it is easy to install and remove. If the jurisdiction decides the system is not effective at its location, it can be removed and the road can be easily returned to its original form.

"The simple installation techniques and adaptable design characteristics have made this construction technique an effective solution with potential to address a variety of traffic issues," says Dr. Wei Zhang, a highway research engineer with FHWA's Office of Safety Research and Development.

Driving Success

Again and again, the SBIR program has produced effective innovations to answer transportation challenges. The program's focus on market-driven solutions helps to achieve successful adoption because all of the innovations are addressing a real need for which a market exists. This creates an environment in which FHWA can advance its strategic goals; a small business with a great idea can find success in a crowded market; and the public benefits from safer, efficient, and more durable infrastructure.

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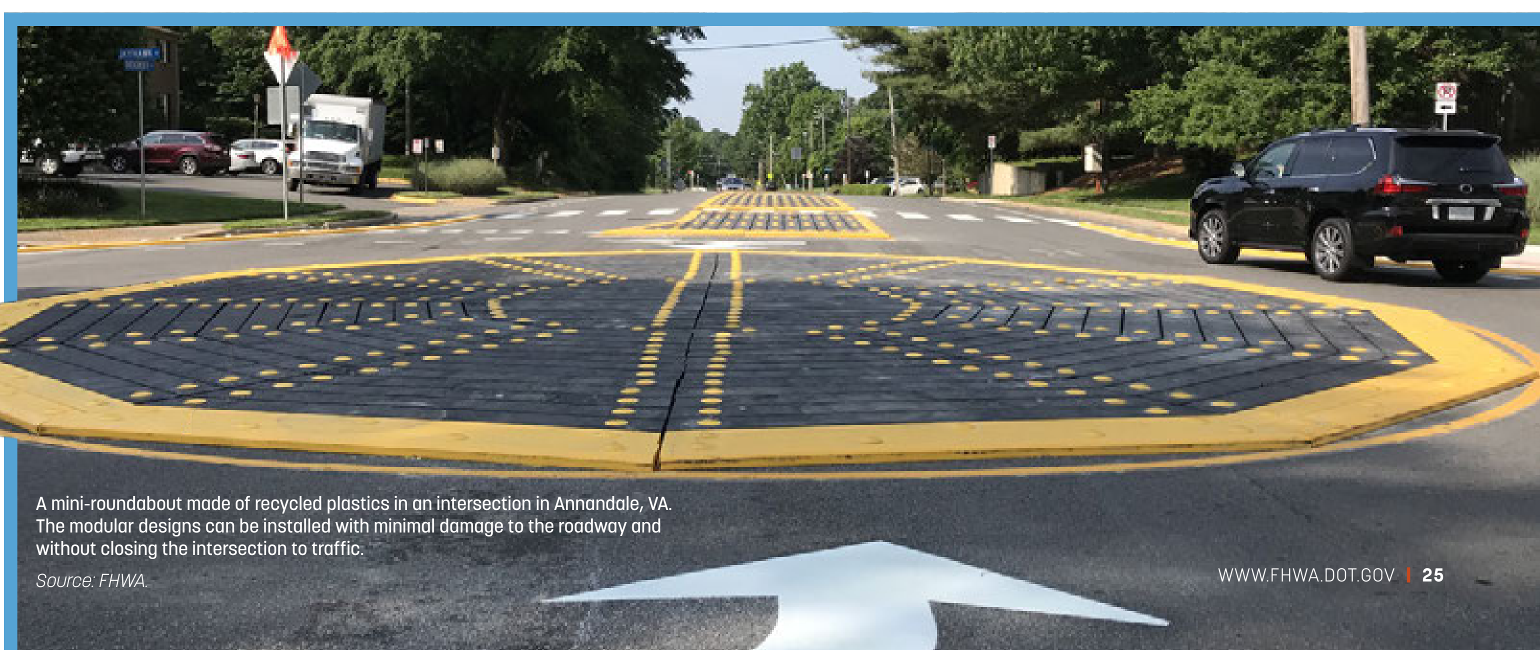
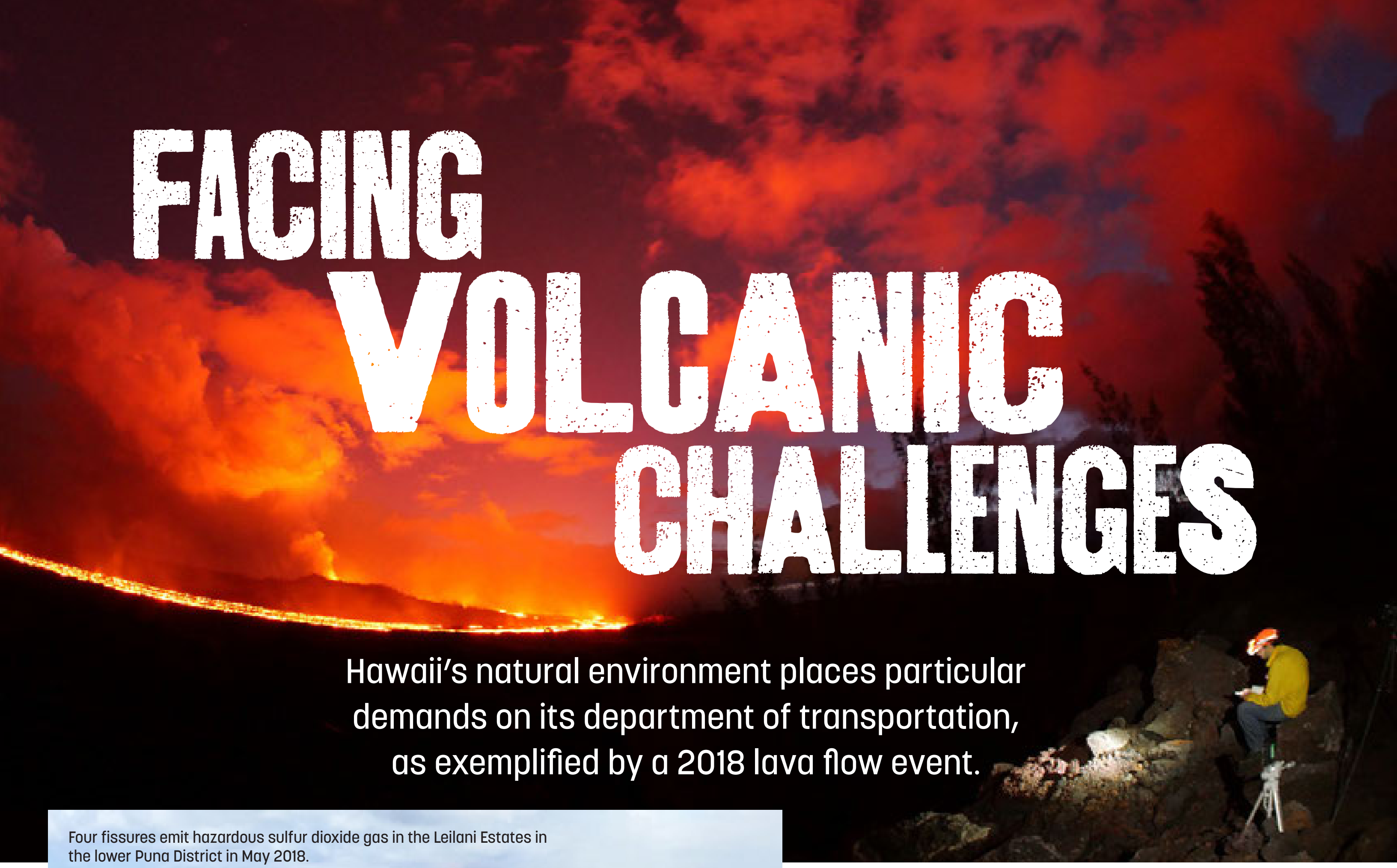
SARAH CIGAS graduated from the University of Southern California in 2020 with a B.S. in civil engineering. She served as a Summer Transportation Internship Program for Diverse Groups intern with FHWA in 2018. Following graduation, she plans to pursue a master's degree in structural engineering.

For more information, contact Craig Thor at *craig.thor@dot.gov* or visit *www.volpe.dot.gov/work-with-us/small-business-innovation-research*.



A mini-roundabout made of recycled plastics in an intersection in Annandale, VA. The modular designs can be installed with minimal damage to the roadway and without closing the intersection to traffic.

Source: FHWA.



FACING VOLCANIC CHALLENGES

Hawaii's natural environment places particular demands on its department of transportation, as exemplified by a 2018 lava flow event.

A geologist from the U.S. Geological Survey makes observations at a lava fissure in July 2018. The volcanic event damaged hundreds of homes and made roads impassable.

Source: U.S. Geological Survey Hawaiian Volcano Observatory.

Four fissures emit hazardous sulfur dioxide gas in the Leilani Estates in the lower Puna District in May 2018.

Source: T. Neal, U.S. Geological Survey.

by **RICHELLE TAKARA**

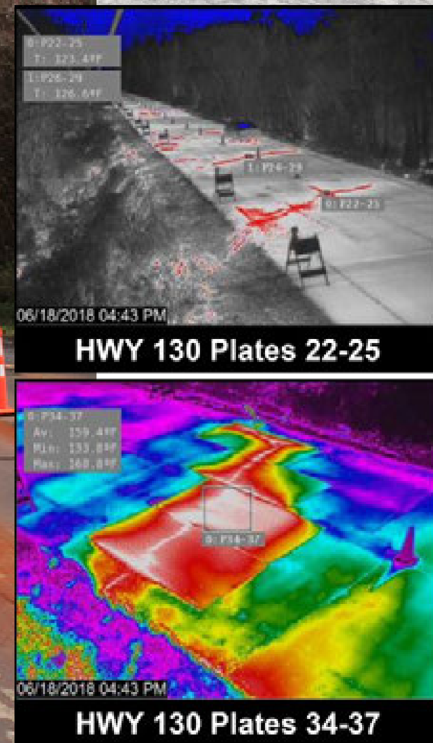
The State of Hawaii endures floods, fires, earthquakes, hurricanes, tsunamis, tornadoes, and waterspouts. In addition, Hawaii also experiences eruptions and lava flows from active volcanoes. All of these events and their effects on highways present the Hawaii Department of Transportation (HDOT) with distinct challenges to incident response and repair.

In 2018 alone, HDOT saw a record-setting flood event and two tropical cyclones, Hurricane Lane and Tropical Storm Olivia. While the volcanoes are always erupting, it is not often that they adversely impact the lives of people and their residences. However, one such event occurred in May 2018, presenting an example of what confronts the State of Hawaii when an emergency arises from natural causes.

Lava Flow in Leilani Estates

The Pu'u 'O'o vent in the East Rift Zone of the Kilauea volcano originally erupted on January 3, 1983, and has continued to erupt for more than 35 years. From May to August 2018, lava from the vent flowed out of fissures in the Leilani Estates residential subdivision of Pahoa, in Hawaii County. Lava poured over streets and prompted a mandatory evacuation of the subdivision.

Three roads provide essential access to this area of Pahoa: Route 130, Route 132, and Route 137. These



Field crews track activity in and around Leilani Estates in June 2018, including observations from cracks near Route 130, shown here with plates installed on the roadway.

Source: U.S. Geological Survey Hawaiian Volcano Observatory.

Thermal cameras enabled HDOT engineers to remotely monitor the surface temperature of plates installed on Route 130.

Source: FHWA.

routes form a triangle around the community. The first sign of lava appeared on May 3 in the middle of the triangle and reached the ocean on May 23. The lava's path crossed under Route 130 and eventually crossed over Routes 132 and 137, making the roads impassable. Consequently, about 2,800 people were evacuated and more than 500 homes destroyed.

Route 130

During the event, the asphalt on Route 130 cracked when lava flowed under it. HDOT opened Route 130 by placing steel plates over the cracks. After installation, the steel plates reached a temperature of approximately 140°F (60°C). If the temperature approached 200°F (93°C), then HDOT would assess the situation and perhaps close the road. The manual monitoring of steel plate temperatures with a thermometer twice a day was not adequate to maintain safety and warn the public of the need to close the road. Therefore, HDOT had to figure out how to provide the public with continuous information on the status of the road.

HDOT needed to monitor the conditions of the road, traffic, and ambient conditions around the site from its office approximately 18 miles (29 kilometers) away. The engineers could view traffic using pan-tilt-zoom cameras and solar cellular-equipped trail cameras. Using thermal cameras to detect the surface temperature of the roadway and sulfur dioxide sensors to get air quality readings, HDOT could monitor the ambient conditions of the area as well. This innovative setup enabled HDOT to make decisions remotely to provide maintenance or to close the roadway if needed.

To provide real-time information to the public, HDOT installed a network of message boards that notified motorists of changing conditions. HDOT also developed a special website to provide the camera images as well as other notices created by HDOT, the county, and Federal agencies about Route 130's conditions.

To address concerns about the rising temperature of the steel plates, HDOT replaced them with a heat-resistant concrete slab constructed out of calcium aluminate cement, sand from British Columbia's

A Hawaii Air National Guard Airman approaches a growing road crack during a volcanic outbreak at Leilani Estates in May 2018.

Source: Senior Airman John Linzmeier, State of Hawaii Department of Defense.

Lava flows continue near Leilani Estates in July 2018.

Source: M. Patrick, U.S. Geological Survey.

Orca quarry, and stainless steel rebar. The heat-resistant concrete slab can support a 20-ton truck with full impact load over a 7-foot (2.1-meter) span and a standard car over a 16-foot (4.9-meter) span. The slab is stable up to 1,500°F (815°C), but cars cannot drive over it if ambient temperatures exceed 800°F (427°C).

"The rapidly changing event made staying two routes ahead of the lava flows imperative," says Edwin Sniffen, the deputy director of HDOT's Highways Division. "In addition to preparing alternate routes along the beach and Chain of Craters Road, we needed to ensure Highway 130 was traversable for as long as practical. The ingenuity of our engineers in utilizing heat-resistant materials and setting up camera and monitoring connectivity in a relative dead spot was essential to keeping our communities connected safely."

Route 132

In August 2018, approximately 3 months after the first flow appeared, the lava appeared to stop its advance. Unfortunately, Highway 132, a major thoroughfare in the lower Puna district, was already inundated with lava. Lava covered the upper and lower parts of the road and left a portion of the road in the middle untouched but isolated, surrounded by lava. This kind of isolated area that forms when lava flows on either side of a hill, ridge, or older lava dome as it spreads from its source is known as a kipuka.

After waiting for a 6-month cooling-off period, Hawaii County started to grade an alignment for a temporary road to replace Route 132. On June 10, 2019, Hawaii County started to restore Highway 132 to its pre-inundation function with two paved travel lanes and shoulders but at a much higher elevation. Originally, an October 5, 2019, deadline was set to complete the road restoration project in order to qualify for 100 percent Federal-aid highway emergency relief funds. However, due to the hot surface temperatures of more than 800°F (420°C) that damaged equipment, the Hawaii County Department of Public Works requested and received a 3-month extension.

Work included rough grading over 109,000 cubic yards of lava rock, placing 3 miles (4.8 kilometers) of asphalt concrete base course, dressing the shoulders, and installing signs and striping. Highway 132 was reopened on November 27, 2019, the day before Thanksgiving. Hawaii County Mayor Harry Kim said, "It's been a long time coming." Mayor Kim praised the work done by Federal and County agencies, which he said, "is beyond belief to me." Many Big Island residents with homes and farms that had been landlocked by lava voiced relief at being able to once again reach the properties that constitute their livelihoods.

Sections of Route 132 were completely covered by lava during the 2018 eruption.

© County of Hawaii Department of Public Works.

Route 11

The area around the Leilani Estates was not the only impacted location. During the eruption, daily earthquakes caused severe damage to Route 11, also called the Mamalahoa Highway, between mile marker 28 and 32 in Volcano Village. HDOT engineers first used ground penetrating radar (GPR) to determine the nature and extent of damage to the highway at specific locations. They made extensive repairs, which involved months of 24/7 lane closures that enabled reconstruction of the roadbed from depths of up to 10 feet (3 meters).

In February 2019, upon completion of site-specific repairs, HDOT performed a followup GPR survey for the corridor between mile markers 28 and 32. The survey confirmed that all subsurface voids and cracks of concern under Mamalahoa Highway were repaired properly.

Next Steps

While Route 132 now provides access to many farms and residences, many decisions remain to be made. Hawaii County is developing a volcanic risk assessment study that will detail the exposure of land, people, and infrastructure to volcanic hazards based on lava zones designated by the U.S. Geological Survey. The county's next steps are to secure Federal funding to restore damaged infrastructure and to decide which assets will be rebuilt and what new infrastructure will be constructed to assist in the county's recovery from this lava event. If certain county roads are not restored, then those funds can be allocated to infrastructure projects that support residential settlement in areas of lower risk. The county needs to balance a process that reduces repetitive losses and residential settlement in high-hazard areas, while also planning for infrastructure assets that serve the region as a whole, including commercial centers and emergency access.

Hawaii County is looking at numerous factors to determine which local roads should be restored and which ones should not. For example, the county is documenting which roads serve as emergency access routes, what response times for fire department and police have been prior to the eruption and today, which roads rely on other roads (including private roads) or infrastructure assets to be restored in order to function, and interest among displaced residents to relocate through a voluntary buy-out program or to return to their original homes.

"Emergencies caused by storms and volcanic eruptions will continue to occur in Hawaii. Communication, innovation, and preparation are critical to addressing them as they arise and keep traffic moving along Hawaii's roads and highways," says HDOT's Sniffen. "The lessons and mindset we learned during this emergency event helped move our capabilities forward as a department."

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For more information, see ***https://www.hawaiicounty.gov/departments/civil-defense/eruption-related-information*** or contact Richelle Takara at 808–541–2311 or ***richelle.takara@dot.gov***.

Lava flows cut off Route 137 near Leilani Estates in May 2018. The Hawaii County Department of Public Works is still coordinating with the Federal Emergency Management Agency to determine whether the road will be reconstructed.

Source: Sgt. 1st Class Thomas Wheeler, State of Hawaii, Department of Defense.

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

Public Information and Information Exchange

USDOT Seeks Innovators for Inclusive Design Challenge

On April 21, 2020, the U.S. Department of Transportation opened Stage I of the Inclusive Design Challenge, a national prize competition seeking solutions to make future automated vehicles more accessible to people with disabilities. Stage I of the challenge will be open for submissions until October 30, 2020. The Inclusive Design Challenge seeks innovative solutions that will enable people with physical, sensory, and cognitive disabilities to use automated vehicles to access jobs, healthcare, and other critical destinations. During two stages of competition, teams will compete to earn a portion of a $5 million prize purse.

idc
INCLUSIVE DESIGN CHALLENGE
SPONSORED BY THE U.S. DOT

Source: USDOT.

Teams from academic and research institutions, the business sector, and technology companies are invited to submit entries. Solutions may include hardware or software ideas intended to enable independent use of automated vehicles by people with disabilities. Stage I of the challenge requests written proposals describing the design solution. Up to 10 semifinalists will be selected and awarded $300,000 each based on their proof-of-concept ideas. In Stage II, semifinalists will compete for a portion of the remaining prize funding by developing prototype demonstrations of their concepts. USDOT anticipates awarding Stage II prizes in summer 2022.

As part of the challenge, USDOT is also encouraging teams to seek input from the disability community, industry, and the research community. Understanding user needs and industry dynamics is critical to developing designs with the greatest potential for future impact. By ensuring that automated vehicles are designed to be inclusive, USDOT expects that the challenge will help enhance future access to critical services, including medical care, for people with disabilities.

For more information, visit *www.transportation.gov/accessibility/inclusivedesign*.

Secretary Chao Announces Grants to Improve Highway Safety in Indian Country

In April 2020, U.S. Secretary of Transportation Elaine L. Chao announced more than $8.9 million for 91 projects to 80 federally recognized American Indian Tribal Nations during her remarks at the National Congress of American Indians.

"These Federal funds will go to American Indian Tribes to improve traffic safety and improve the quality of life for Tribal communities," said Secretary Chao.

The $8.9 million will come from the Federal Highway Administration's Tribal Transportation Program Safety Fund (TTPSF). Nearly 60 Tribes will receive funding to assist in the development or update of a transportation safety plan. A library of such plans is online at *www.tribalsafety.org/safety-plans-library*. Other funded projects include roadway departure countermeasures, road safety audits, pedestrian facilities, roundabouts, intersection improvements, and data management systems.

A full list of grants is available at *https://highways.dot.gov/federal-lands/programs-tribal/safety/funds*.

Every Day Counts Launches Storyboards

The Federal Highway Administration's Every Day Counts (EDC) initiative recently shared its first storyboard, an interactive digital slideshow that incorporates images, video, and graphics to create a highly visual experience. The inaugural effort highlights the EDC-5 innovation Focus on Reducing Rural Roadway Departures (FoRRRwD) and promotes greater use of curve warning signs.

More than 36,000 people die each year on the Nation's highways. More than 25 percent of those fatalities occur on horizontal curves—curves that change a road's direction or alignment. Curve warning signs, such as chevrons, are cost-effective countermeasures proven to reduce crashes on horizontal curves. For example, chevrons reduce nighttime crashes on curves by 25 percent.

For more information, visit *https://safety.fhwa.dot.gov/forrrwd/curvesignstoryboard/index.html*.

FMCSA Updates Hours of Service Rules

In May 2020, the Federal Motor Carrier Safety Administration (FMCSA) published a final rule updating hours of service (HOS) rules for commercial motor vehicle drivers to provide greater flexibility for drivers without adversely affecting safety.

First adopted in 1937, FMCSA's HOS rules specify the permitted operating hours of commercial drivers. In 2018, FMCSA authored an Advanced Notice of Proposed Rulemaking to receive public comment on portions of the HOS rules to alleviate unnecessary burdens placed on drivers while maintaining safety on the Nation's highways and roads. Subsequently, in August 2019, the agency published a detailed proposed rule, which received an additional 2,800 public comments.

Based on the detailed public comments, FMCSA's final rule on HOS offers four key revisions to the existing HOS rules. First, the agency will increase safety and flexibility for the 30-minute break rule by requiring a break after 8 hours of consecutive driving and allowing the break to be satisfied by a driver using on-duty, not driving status, rather than off-duty status. Second, FMCSA will modify the sleeper-berth exception to enable drivers to split their required 10 hours off duty into two periods: an 8/2 split, or a 7/3 split—with neither period counting against the driver's 14-hour driving window. Third, the updated rule will modify the adverse driving conditions exception by extending by 2 hours the maximum window during which driving is permitted. Finally, FMCSA will change the short-haul exception available to certain commercial drivers by lengthening the drivers' maximum on-duty period

Every Day Counts created an interactive storyboard highlighting the benefits of curve warning signs.
Source: FHWA.

from 12 to 14 hours and extending the distance limit within which the driver may operate from 100 air miles to 150 air miles.

The new HOS rule will be effective beginning September 29, 2020. The complete final rule is available at *www.fmcsa.dot.gov/regulations/hours-service/hours-service-drivers-final-rule*.

TRB Recordings: Landscape Design Practices for Roadside Water Management

In April 2020, the Transportation Research Board (TRB) released a straight-to-recording series that presents highlights and findings of the National Cooperative Highway Research Program's Domestic Scan 16-02 on Landscape Design Practices for Roadside Water Management. This scan investigated how transportation agencies are applying principles and practices of green infrastructure for roadside water management to mitigate adverse impacts of flooding, drought, and temperature extremes affecting their infrastructure. The scan findings focus on eight critical areas that impact the overall success of green infrastructure practices. The report is available at *http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP20-68A_16-02.pdf*.

The videos offer presentations from Garrett Jackson of the Washington State Department of Transportation, John L'Etoile of the Nevada Department of Transportation, and William Fletcher, retired from the Oregon Department of Transportation. They are available on demand at no charge at *https://vimeo.com/showcase/7050291*.

Source: TRB

TRB recently recorded presentations of highlights from the National Cooperative Highway Research Program's scan on landscape design practices.
© National Academy of Sciences.

FMCSA recently updated hours of service rules for commercial motor vehicles.
© IM_photo / Shutterstock.com.

Advancing Workforce Development: Leading a Performance-Based Culture

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

With ever-increasing demands on time and resources, transportation maintenance departments need an efficient and innovative way to invest in their workforce and train their employees to rise to the roles of managers and supervisors. To fill that need, the National Highway Institute (NHI) offers a newly updated course, Maintenance Leadership Academy (MLA) (FHWA-NHI-134063). This intensive training program supports workforce development by delivering a streamlined path to acclimate new managers to maintenance leadership roles, improve organizational decision-making, and support a performance-based maintenance culture.

The MLA will jump-start maintenance supervisors and other rising leaders in their management roles by providing both technical and leadership training to help participants drive innovation on the job. Attendees will learn how to develop and lead a performance-based workplace, embrace a strategic and measurable approach to managing resources, and maximize highway system performance.

Fulfilling demands for both career development and advancing industry knowledge, the MLA teaches effective leadership skills while providing a deeper understanding of various processes, methods, and materials that will maintain and preserve an organization's bridge and highway systems.

Past host and current instructor Greg Duncan says, "At the first session in Tennessee, I saw direct results from district maintenance managers attending the program. Improvements included immediately reevaluating planned pavement preservation needs lists and collaborating with other regional managers for problem solving. Although the training was intense and a huge time commitment, each participant expressed satisfaction knowing that they gained skills they could use to advance maintenance practices for our agency."

Updated for 2020: Streamlined and Targeted

NHI recently updated the MLA with feedback and insight from experts in the field, including the Federal Highway Administration's Office of Infrastructure, the Resource Center, State departments of transportation, and maintenance specialists from the American Association of State Highway Transportation Officials. The updated MLA has been streamlined to be more leadership focused and relevant to the workforce development needs of State maintenance departments. This includes updating the training's six modules across technical topics while weaving in effective leadership skills.

Inspiring Leaders

One of the hosts of the updated course, Greg Selstead, explains that a maintenance supervisor's role doesn't just require leadership, it's also about guiding a cultural shift.

"The heart of this update reflects an emphasis on leading a performance-based maintenance culture," says Selstead. "The essence of training our maintenance leaders how to establish this type of culture sets the tone in this first module and is the common thread woven throughout the course."

This shift will benefit the industry, Selstead believes, because a performance-based culture supports achievable agency goals and transparent decisionmaking processes. By incorporating performance data analysis, asset management, and evaluative strategies, the MLA will give participants the skills and information they need to make better decisions for their agencies.

NHI redesigned the MLA to inspire a leadership mindset in addition to providing advanced technical knowledge as a workforce development course. By framing the technical modules around performance-based measures and evaluations, the course teaches participants to lead an effective, data-driven maintenance program. In turn, this structure promotes quality results in all areas of maintenance work.

Academy Structure

One of the unique benefits of the MLA is the flexibility in its structure. The course consists of six modules, combining self-paced lessons (online and paper-based) with instructor-led classroom expertise. The classroom portion can be broken into two or three sessions, if requested. A typical course outline runs 12 weeks from the date of the first web conference orientation through the final

> **"By sending staff to the MLA, transportation agencies can expect to accelerate the learning curve for new maintenance managers or supervisors and to broaden the skillset for those with more experience. The workshops were also redesigned to increase participant engagement and reinforce how leading practices presented in the curriculum can be implemented in their home agency."**
>
> *Greg Duncan, MLA Instructor*

NHI's courses are designed to engage adult learners and provide hands-on, experience-driven, active learning opportunities. Participants in a 2016 MLA course in Tennessee get hands on with their learning as they take the classroom outside.
Source: NHI.

day of classroom training. Because of its blended structure, the course can be compressed or spaced out based on the needs of the host State.

To meet the demands of the industry, the streamlined MLA now covers all relevant material in less time:

- 1-hour orientation web conference
- Approximately 16.5 hours of independent study (reduced from 32.5 hours)
- 10.5 days of instructor-led, classroom training (reduced from 12 days)

The lessons focus on relevant and needed skills for current and future supervisors. Many of the lessons are self-paced to enable the participants to work on their own schedules. This condensed structure enables new or inexperienced professionals to come up to speed quickly, reducing time away from their jobs.

The updated MLA includes a revised curriculum with modules on the following topics:

- Leading a performance-based maintenance culture
- Pavement and bridge preservation
- Roadside maintenance and drainage
- Environmental protection
- Weather-related operations
- Traffic and work zone safety

The modules are designed to provide applicable, state-of-the-practice technical knowledge in each subject area. The relationships between the modules are emphasized, enabling participants to apply skills learned in one module to another. This reinforces the effectiveness of a planned, performance-based approach.

Workforce Development: Who's Ready to Lead?

The MLA is a comprehensive and intensive career development course. It is designed to quickly acclimate new or inexperienced maintenance supervisors, superintendents, and managers to their expanding or evolving roles.

Potential participants should already have at least a basic understanding of maintenance operations at the county, regional, or State level. This includes a familiarity with oversight, quality assurance, handling materials, scheduling, budgeting, and planning. Participants should also have advanced skills in maintenance activities, such as pavement preservation.

With a deep dive into the six subject modules, participants will develop an indepth understanding of the complex decisionmaking processes of their agency, as well as the value of a performance data-driven maintenance culture. Participants will gain an applicable knowledge base of planning, scheduling, quality control, customer service, asset management, pavement and bridge preservation, contract management, and environmental responsibilities.

NHI-Supported Regional Sessions

As part of its 50th anniversary efforts for 2020, NHI pledged its support for regional MLA programs. Through the institute's partnership with FHWA's Office of Infrastructure, supported sessions will continue beyond the current year. NHI plans to host one regional offering each year in locations across the United States.

Though State-hosted MLA sessions can benefit an entire department in one swoop and may be recommended for efficiency, regional collaboration is a frequently pursued option. Sending participants to a regional session offers flexibility in scheduling, enabling agencies to stagger the training of their future leadership.

These regional sessions also offer other benefits, including opportunities to share practices across geographic and political boundaries. Past participants have found regional sessions to be highly effective, as they gained a broader understanding of the material due to the diversity in experiences and ideas exchanged.

How to Host or Attend a Training Course

State and local agencies interested in hosting the MLA can host the course at a discount through 2021. The cost reduction is reflected in the course description on NHI's website.

Interested hosts can submit a Host Request Form or find more information about hosting this course through NHI's website at *www.nhi.fhwa.dot.gov/training/host.aspx*.

Individuals interested in attending a currently scheduled session can also benefit from NHI's discounted pricing. For more information on this course or to register for an MLA session, visit *www.nhi.fhwa.dot.gov*.

In addition to providing career development through leadership and technical training, the MLA awards eight continuing education credits upon successful completion.

GAY DUGAN is an NHI training program manager.

CHRISTINE KEMKER is a contractor for NHI.

Collaboration is an important aspect of the MLA. Participants are given the opportunity to learn from each other, broadening their experiences and gaining new ideas to bring back to their agencies.

Source: NHI.

Continuing Education Credits

NHI invites professionals interested in earning continuing education units or professional development hours to visit *www.nhi.fhwa.dot.gov* to browse the complete digital course catalog, which lists more than 400 courses spanning 18 program areas.

NHI is approved as an Accredited Provider by the International Association for Continuing Education and Training (IACET). As an IACET Accredited Provider, NHI offers continuing education units for its programs that qualify under the ANSI/IACET Standard.

COMMUNICATION PRODUCT UPDATES

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

COMPILED by **LISA A. SHULER OF FHWA'S OFFICE OF CORPORATE RESEARCH, TECHNOLOGY,** and **INNOVATION MANAGEMENT**

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Analysis Procedures for Evaluating Superheavy Load Movement on Flexible Pavements, Volume VI: Appendix E, Ultimate and Service Limit Analyses

Publication Number: FHWA-HRT-18-054

The movement of superheavy loads (SHLs) on the Nation's highways is an increasingly common, vital economic necessity for many important industries, such as chemical, oil, electrical, and defense. Many superheavy components are extremely large and heavy (gross vehicle weights in excess of a few million pounds), and they often require specialized trailers and hauling units. Often, SHL vehicles have been assembled to suit the load being transported, and therefore, the axle configurations have not been standard or consistent. Accommodating SHL movements without undue damage to highway infrastructure requires the determination of whether the pavement is structurally adequate to sustain the SHL movement and protect any underground utilities. Such determination involves analyzing the likelihood of instantaneous or rapid load-induced shear failure of the pavement structure.

The goal of this project was to develop a comprehensive analysis process for evaluating SHL movement on flexible pavements. As part of the project, a comprehensive mechanistic-based analysis approach consisting of several analysis procedures was developed for flexible pavement structures and documented in a 10-volume series of FHWA reports.

Volume VI of the series details the analysis procedures for investigating the risk of ultimate and localized shear failure under SHL-vehicle movements. The report also presents a deflection-based service limit analysis for limiting the amount of pavement surface deflection under an SHL-vehicle.

This report is intended for use by highway agency pavement engineers responsible for assessing the structural adequacy of pavements in the proposed route and identifying mitigation strategies in support of the agency's response to SHL-movement permit requests.

The document is available to download at *www.fhwa.dot.gov/publications/research/infrastructure/pavements/18054*.

Simulator Assessment of Alternative Lane Grouping at Signalized Intersections (TechBrief)

Publication Number: FHWA-HRT-19-034

This technical summary presents the study results for research conducted in a highway driving simulator to evaluate driver behavior and sign comprehension during reversible-lane operations compared to conventional-lane operations.

Throughput at signalized intersections with high left-turn demand is a common cause of bottleneck for traffic flow. Dynamic lane-grouping strategies offer cost-effective methods for increasing operational efficiency within existing rights-of-way. Previous traffic simulations suggest that reversible left-turn lanes can significantly increase throughput at intersections where left-turn demand is high. However, the operational benefits offered by reversible-turn-lane designs depend on safe and proper use by drivers.

Because reversible lanes make use of existing infrastructure and are dependent on time of day, they require clear and adaptive signs and signals to indicate the active or closed status of a reversible lane and to control alternative-lane assignment during active periods. Reversible-lane designs may also expose drivers to unfamiliar situations, such as sharing a lane with opposing traffic waiting at the far side of the intersection. In these cases, appropriate signs can mitigate unsafe driving behaviors and driver discomfort or confusion. In addition, improved signs and markings may aid in minimizing issues observed at existing reversible-lane interchanges, such as incorrect or missed turns and lane changes within the intersection.

The document is available to download at *www.fhwa.dot.gov/publications/research/safety/19034*.

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