Public Roads

www.fhwa.dot.gov
November/December 2015

How to Tune a Simulator
Reusing Bridge Foundations
Adaptive Roadway Lighting

U.S. Department of Transportation
Federal Highway Administration

Public Roads

November/December 2015 www.fhwa.dot.gov Vol. 79, No. 3

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

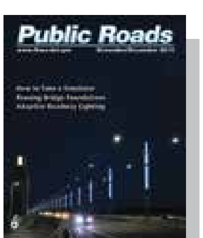
Articles

Page 2

Page 22

Page 26

Departments



Front cover—The Rhode Island Department of Transportation recently installed this lighting on the Sakonnet River Bridge. The treatment uses high-efficiency, long-life LED luminaires in conjunction with light guides lined with optical lighting film for dramatic effect. For information on another emerging lighting technology that could be coming to a roadway near you, see "The Future of Roadway Lighting" on page 32 in this issue of PUBLIC ROADS. *Photo: Paul Lutkevich, Parsons Brinckerhoff.*

Back cover—The Federal Highway Administration's highway driving simulator, shown here at the Turner-Fairbank Highway Research Center in McLean, VA, supports a variety of human factors research studies. Recent tuning of the motion-base system enables greater freedom of movement and more realistic simulations for test drivers. For more information, see "Where the Laboratory Meets the Road" on page 2 in this issue of PUBLIC ROADS.

U.S. Department of Transportation
Federal Highway Administration

U.S. Department of Transportation
Anthony Foxx, *Secretary*

Federal Highway Administration
Greg Nadeau, *Administrator*

Office of Research, Development, and Technology
Michael Trentacoste, *Associate Administrator*

Lisa A. Shuler, *Editor-in-Chief*

TaMara McCrae, *Publication Manager, Creative Director*

ICF International (Contractor):
Norah Davis, *Editor*
John J. Sullivan IV, *Managing Editor*
Alicia Sindlinger, *Associate Editor*

Lisa A. Shuler, *Distribution Manager*

Debra S. Elston, *Editorial Board Manager*

Public Roads (ISSN 0033-3735; USPS 516-690) is published bimonthly by the Office of Research, Development, and Technology, Federal Highway Administration (FHWA), 1200 New Jersey Avenue, SE, Washington, DC 20590. Periodicals postage paid at Washington, DC, and additional mailing offices.

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

The editorial office of *Public Roads* is located at the McLean address above.
Phone: 202–493–3375. Fax: 202–493–3475.
Email: lisa.a.shuler@dot.gov.

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

The electronic version of *Public Roads* can be accessed through the Turner-Fairbank Highway Research Center home page (www.fhwa.dot.gov).

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

Guest Editorial

TIM: An Important Operations Strategy

Over the past 2 years, PUBLIC ROADS has featured a series on traffic incident management (TIM) to demonstrate the critical role that operations plays in efficient and effective highway management. The first two articles, "Successfully Managing Traffic Incidents Is No Accident" (July/August 2013) and "Training Millions of Responders" (November/December 2013), introduced the concept of TIM and described the Federal Highway Administration's efforts to help train 1 million responders over the next decade.

The TIM responder training resulted from the second Strategic Highway Research Program's (SHRP2) suite of reliability products. The second round of Every Day Counts initiatives, known as EDC-2, aided FHWA in accelerating course delivery. With the push from EDC-2, FHWA trained 50,000 responders almost 6 months earlier than planned. Just 3 months after EDC-2 ended, FHWA doubled the number of TIM practitioners trained to more than 115,000 and developed a cadre of 6,500 instructors delivering the course nationwide.

The next three articles explored TIM from the perspectives of key partners. "Living in the Line of Duty" (July/August 2014) addressed the risks faced by firefighters and first responders at the scene of a crash. "Clearing Crashes on Arterials" (March/April 2015) looked at cost-effective resources available from local departments of transportation and public works, often deployed in support of TIM operations on arterials. "A Pivotal Job for Police" (May/June 2015) spotlighted how the collection of data by State and local law enforcement agencies supports the measurement of TIM performance.

In this issue of PUBLIC ROADS, the article "Supporting Hometown Heroes" (page 39) underscores the value of institutionalizing TIM at all levels of government and within corresponding stakeholder disciplines. Over time, as champions have encouraged their leadership to support this operational strategy, TIM has become entrenched in some organizations. However, other programs have faltered when their charismatic and passionate champions moved on. This series concludes with a call for all TIM partners to collaborate with their political and organizational leadership and metropolitan planning organizations to ensure that TIM becomes a critical mission, reflected in their organizations, budgets, and plans.

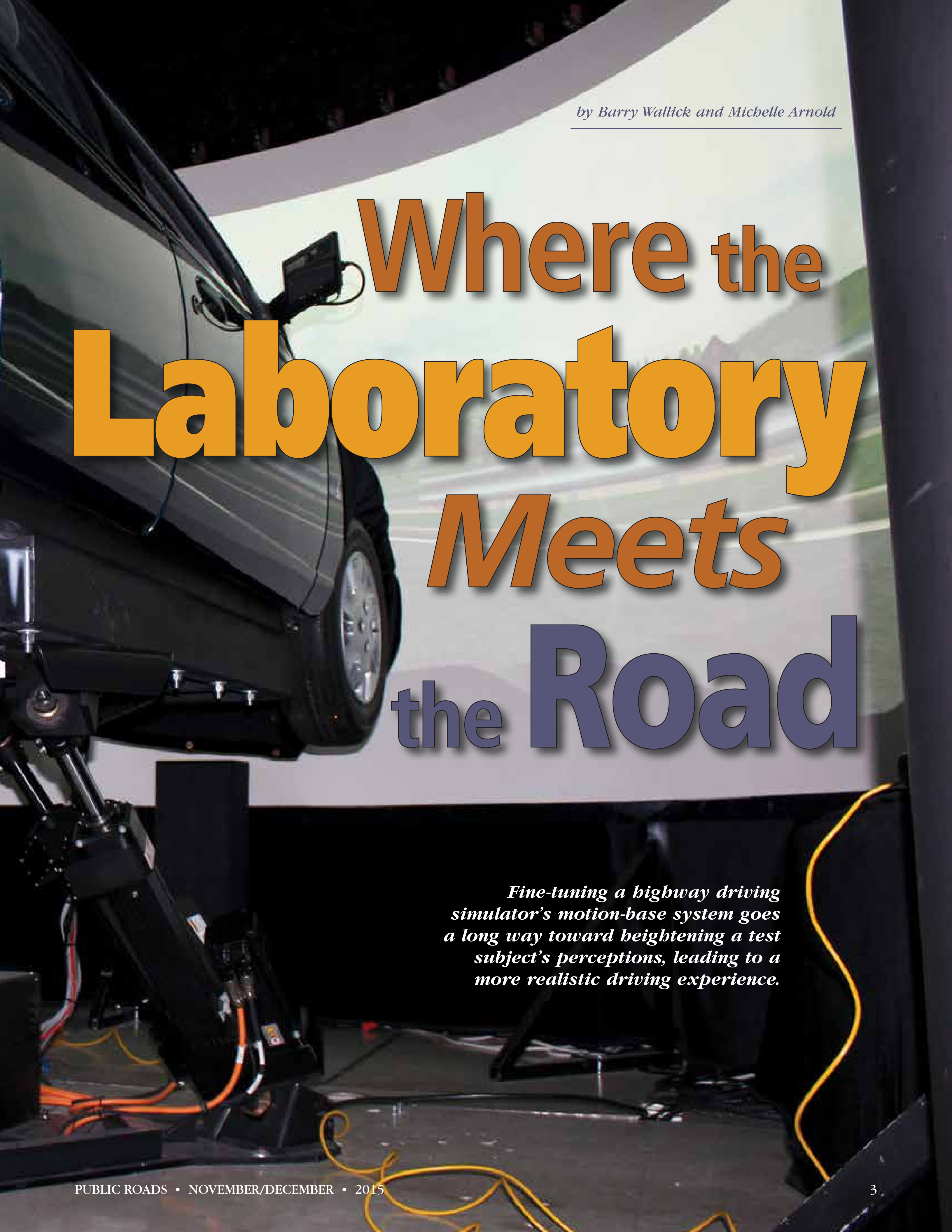
FHWA is highlighting TIM because it showcases the critical role of nontraditional partners in operations strategies. But TIM constitutes just one of many approaches that jurisdictions employ to help travelers move faster, more safely, and with fewer disruptions. Efforts to manage the impacts of weather and work zones, better apply the standards outlined in the *Manual on Uniform Traffic Control Devices*, and implement intelligent transportation systems to support integrated corridors, traffic management centers, value pricing, modeling and analytics, and freight operations will continue to shape travel reliability, motorist and responder safety, and community livability, along with TIM.

The work described throughout this series would have been impossible without the support of partners from fire and rescue, local transportation and public works departments, and law enforcement, as well as FHWA division office staff and their State DOT counterparts who help provide the leadership, coalition building, and TIM training that underlie reliable highway operations and incident response.

From compiling best practices to promoting use of the National Incident Management System as the common language at the scene of a crash, FHWA's Office of Operations will continue to strengthen these multidisciplinary partnerships to improve incident operations among public safety partners across the country.

Jeffrey A. Lindley
Associate Administrator
FHWA Office of Operations

The highway driving simulator at the Turner-Fairbank Highway Research Center (shown here) has a motion base that offers six degrees of freedom. A recent effort to fine-tune the motion base helps ensure that future experiments will provide the driver with a more accurate perception of starting, stopping, turning, and bumps, which in turn improves research results.



by Barry Wallick and Michelle Arnold

Where the Laboratory *Meets* the Road

Fine-tuning a highway driving simulator's motion-base system goes a long way toward heightening a test subject's perceptions, leading to a more realistic driving experience.

Understanding how drivers react to stimuli in the roadway environment is critical to improving the design of U.S. roads. Driving simulators are among the tools that human factors researchers use to assess motorist behavior. Driving simulators that are designed for research provide several advantages over the collection of data in real-world environments. Where the safety of a design is in question, a simulator can enable observation of a driver's performance without the risk of injury. Driving simulators also enable control over traffic and weather, and can ensure the exact repeatability of conditions, which is important in isolating cause and effect.

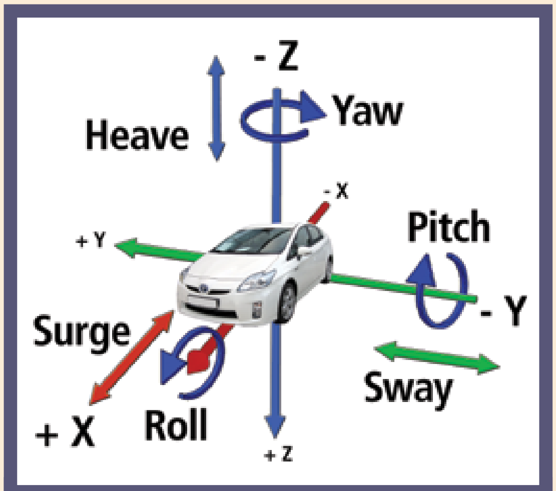
For instance, researchers can specify roadway scenarios and events to simulate specific interactions between vehicles and pedestrians. They also can repeat simulations without waiting for those interactions to occur naturally in particular real-world locations.

Driving simulators used for highway research range from simple desktop units with a monitor, steering wheel, brake, and accelerator pedals to large domes that enclose a complete vehicle mounted on a complex, eight-degrees-of-freedom motion platform that offers a 360-degree field of view. Motion platforms add to the realism of the simulation by offering additional motion cues (proprioceptive, vestibular) to better simulate real-world driving, immersing drivers in the experimental conditions.

However, presenting motion cues that are perceived as realistic to participants in driving simulator research presents numerous challenges. All motion platforms are limited in their range of motion before they must return to a neutral position. The goal is to impart to participants realistic perceptions of acceleration, braking, and turning, while staying within the platform's limited range of motion.

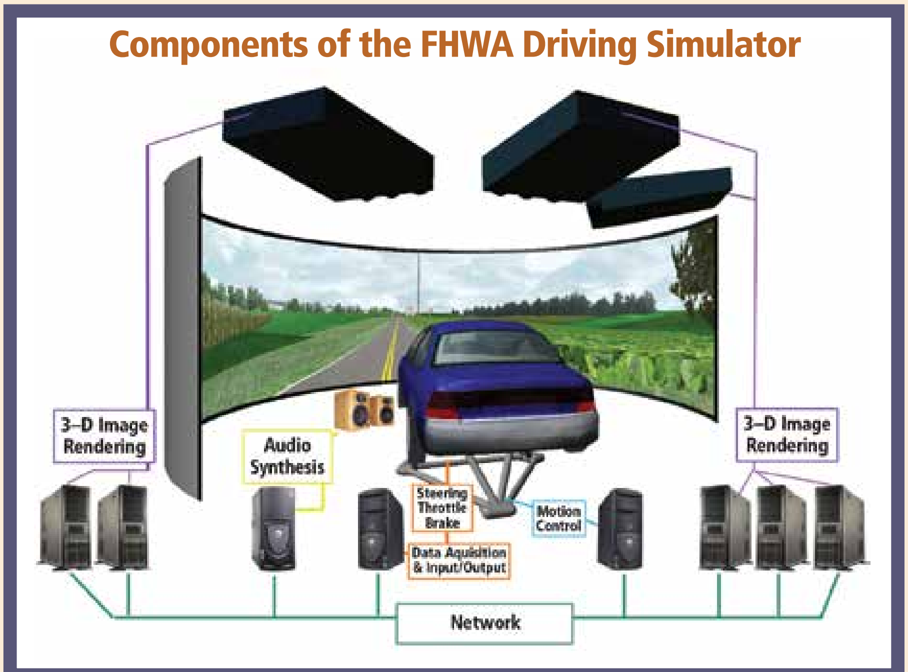
Researchers have used driving simulators in a variety of research and development applications. According to Chris Monk, chief of the Human Factors/Engineering Integration Division at the National Highway Traffic Safety Administration, "driving simulators have been used for developing and visualizing infrastructure, testing advanced safety systems that warn drivers, driver distraction research, and analyzing driver behavior, among other applications."

More specifically, at the Federal Highway Administration, transportation safety specialists and engineers can "drive" a simulated road before it is built to verify signage, pavement markings, lighting, emergency response access, and emergency traffic flow. FHWA's Turner-Fairbank Highway Research Center is home to a motion-base highway driving simulator with a virtual 360-degree field of view generated by three ultra-high-definition projectors and supplemented with three liquid crystal display (LCD) monitors that simulate rearview mirrors. The simulator's sound system provides engine, wind, and tire noise, as well as other environmental sounds. Three-dimensional digital image-generation software offers a scalable, flexible, and customizable environment for creating real-time, fully interactive driving simulations.



A simulator with a motion base that has six degrees of freedom facilitates simulation of the following parameters: pitch, yaw, roll, forward/back (surge), left/right (sway), and up/down (heave).

The FHWA highway driving simulator was recently upgraded with a new hexapod motion base with six degrees of freedom. The parameters of a six-degrees-of-freedom motion base are roll, pitch, yaw, x (linear forward/backward), y (linear left/right), and z (vertical). The visual system projects images within the driver's field of view onto a cylindrical screen surrounding the vehicle.



The components of the highway driving simulator include a motion base, a projection screen, projectors, audio equipment, a data acquisition system, and a three-dimensional image rendering system.

As the driver abruptly changes lanes in the driving simulator, the motion base responds by tilting the car to the left side, providing the driver with vestibular (that is, affecting the perception of body position and movement) stimuli.

The visual scene is synchronized with the motion base's movement to enable the scenes to correlate exactly with driver controls, thus maximizing realistic perception. However, as part of the upgrades to the motion base, the laboratory staff needed to ensure that the motion-base system is finely tuned to provide the best perception for drivers.

"Tuning is critical to increase the realism and validity of the driving experience, while decreasing the likelihood of causing users to experience simulator sickness," says David Yang, Human Factors team leader at FHWA. "That's when test drivers feel discomfort caused by incompatible signals from visual—motion sensing—systems." Aside from being unpleasant, simulator sickness can affect the reliability of measurements.

The team tuned the motion base, including all of the relevant system enhancements, to improve test drivers' perception of the connectedness between the motion base and the visual system display. Here's how they did it.

Tuning for Perception And Data Collection

The goal in tuning the simulator is to adjust the system functions systematically and methodically to achieve the most realistic driving experience feasible. Because the motion base was the major system to be significantly upgraded, it was the starting point for system tuning. However, other simulator functions fed into the overall solution. For instance, steering, acceleration, and braking are all key components in effective functioning of the highway driving simulator.

Creating a Roadway Layout

From a practical standpoint, the first step was for the researchers to employ a field research vehicle to drive real-world roadway layouts. This would help determine which layouts would enable starting, stopping, and turning maneuvers that would fall within the comfortable range of control for a typical driver. This roadway layout would serve as the baseline for tuning the simulator.

The field research vehicle, an instrumented sport utility vehicle capable of collecting data such as vehicle speed, acceleration, and other measures, was used to test proposed roadway layouts that would be modeled and programmed to test the motion base of the simulator. The field vehicle used the test track at the Federal Law Enforcement Training Center in Cheltenham, MD. If a proposed roadway layout was found to be uncomfortable to drive, for example, if turns could not be made comfortably at the desired speed, then that roadway layout would be dropped from further consideration. After screening out unrealistic layouts, the remaining layouts were then modeled and programmed into the simulator and used for perception testing of the motion base.

Simulator Perception Feedback

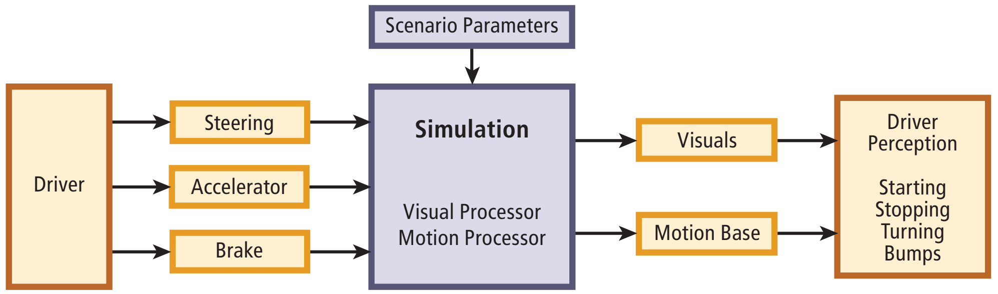
To begin the tuning process for the motion base system, which includes the hexapod apparatus that enables the vehicle to move with six degrees of freedom, a core group of simulation engineers and psychologists who research human factors performed the initial testing. This testing was an iterative process, and each change to the motion-base settings achieved a more refined level of realism for the driver. The team tested the perception of motion after each change to the motion base by driving the simulator. Each team member evaluated the perceptions of steering, acceleration, braking, and turning, and their feedback led to increased refinement of driver perception.

If more than one of the core members responded with similar negative feedback, the research team continued to seek a combination of settings that was acceptable to all. For instance, when braking, the motion system tilts the car forward to simulate the feeling produced when a car slows but inertia causes the driver's body to attempt to maintain the current velocity. If the forward tilt is perceived as something other than a typical deceleration, that perception is a false cue. In extreme cases, a false deceleration cue can be perceived as spinning or sliding (as if on ice) rather than as a change in speed. This was resolved by filtering out small parameter changes to the motion base after the visual scene indicated a stop in motion.

Tuning and Testing

The configuration of the motion base includes three modes with 100 variable parameters total. The modes indicate the amount of "washout"—none, medium, or full—that occurs in the movement

Functions That Feed Into the Simulator



of the motion base. Washout is the ability of the software to anticipate what the motion base will do next by pre-positioning the motion base. For example, if the car is coming to a stop, the motion base will gently move to the rear-most location so that upon acceleration, the motion base can lunge forward and provide the perception of acceleration.

An example of a parameter for a mode is a variable that specifies the allowable distance that the motion base can travel in the x, y, or z directions. One hundred variables produces an extremely large number of possible combinations of settings for a tuning exercise. Therefore, a subject matter expert with extensive experience in motion-base driving simulators, equations of motion, and vehicle dynamics was brought in to select the initial settings by tuning the simulator to a baseline level. The expert was able to reduce the number of settings to be considered during tuning to one mode of operation and 20 parameters that were of the most significance.

For each track layout—a highway scenario and a driving maneuver (acceleration, braking, turning, and slalom)—the core testers conducted runs to ensure that the perceptibility was acceptable, that is, as realistic as possible. After the core team agreed upon the acceptable driving perceptions for all layouts and maneuvers, the research team recruited 10 volunteers, all of whom were FHWA employees and contractors, to evaluate the perception of motion during longitudinal acceleration and braking, turning, and negotiation of a slalom. The team then collected additional feedback to help validate the selected motion system settings.

For example, to evaluate the motion during acceleration and braking, the team developed a questionnaire to evaluate the quality of the perceived motion and whether any false cues were present. Acceleration was tested from 0 miles per hour (mi/h) (0 kilometers per hour [km/h]) to each of the following speeds: 10, 30, 40, and 50 mi/h (16, 48, 64, and 80 km/h). Two different rates of acceleration were rated: moderate and hard. Once at the assigned speed, the participants were asked the following series of questions:

1. How realistic did the acceleration feel? Rate it on a scale from 1 to 7, where 1 represents "not at all realistic" and 7 is "very realistic."
2. While accelerating, did you ever feel like you were decelerating?
3. Did you feel as though you were being tilted up or down?
4. Overall, how acceptable was the motion cueing?

For the second and third questions, if the answer was "yes," the participant was also asked to rate how strong the feeling was.

The researchers also tested deceleration from braking in a similar manner. In fact, after answering the acceleration questions for a particular speed, the participants were asked to brake either moderately or hard and then answer a similar set of questions. Analogous tests were conducted for turns of various radii and for a slalom course at two different speeds.

Perceptions of Acceleration and Braking

Participants gave ratings for the realism and acceptability of the simulator's acceleration that were nearly identical (so only the acceptability ratings are presented here). For acceptability, the mean ratings ranged from 5.3 to 5.7 on the 7-point scale. The research team judged these ratings to be satisfactory. A few of the 10 participants reported a slight indication of false cueing. In all cases of reported false cues, the participants indicated that when they completed the acceleration, they felt a slight deceleration. In most cases, that feeling was rated a 3 on a scale from 1 to 7, where 1 represented "not very noticeable" and 7 represented "very noticeable."

The researchers also deemed the participants' acceptability ratings for motion cueing related to braking to be acceptable, with mean ratings from 5.0 to 5.8 on the 7-point scale. Most of the participants perceived tilting while braking, but the researchers attributed this feeling to the motion system dipping the nose of the car, as would be expected when decelerating, as well as to induce a perception of sustained deceleration. There were only three reports of false cues (for example, feelings of acceleration at some point during braking) across dozens of trials, and even in those cases, the participants judged the overall perception as acceptable.

Perceptions of Turning

The researchers asked participants to rate their perception of turns with turn radii of 131 and 984 feet (40 and 300 meters), each with deflection angles of 60 and 90 degrees. (The deflection angle is the change in compass heading, so that a 90-degree deflection would be a right angle change in direction.) All turns were made while holding the speed constant. The speeds tested ranged from 5 to 30 mi/h (8 to 48 km/h), except that the higher speeds were not used with the 131-foot (40-meter) radius and the lowest speeds were not used with the 984-foot (300-meter) radius because the researchers were testing normal driving behavior.

Mean acceptability ratings ranged from 5 to 7, where 1 represented "not at all acceptable" and 7 was "totally acceptable." The participants provided a mean

A researcher in the control room monitors testing of the motion base, while a test subject operates FHWA's highway driving simulator.

rating above 5 (on the same 7-point scale) for their overall perceptions of the turning maneuvers for all speeds, radii, and deflections.

Sustained turning, such as what a driver experiences traversing a roundabout, is challenging to simulate, but turns of shorter durations tend to be perceived as more realistic. "Turning is a difficult perception to simulate, compared to how a person would feel in the real world," says Jason Williams, a senior software engineer with Textron Systems Support Solutions who works on highway driving simulators. "It is a difficult perception to simulate because there is a physical limit to the movements of a six-degrees-of-freedom motion base, which is truncated when longer, sustained forces are usually experienced by drivers in real-world turning maneuvers, such as when traversing a roundabout." However, the results indicate that the motion base does simulate the initial force of turning and provides drivers with a realistic perception of shorter turns, such as lane changes.

Perceptions of Slalom Maneuvers

The participants drove through a simulated slalom course set up with large cones placed 100 feet (30.5 meters) apart (distance chosen for reasonability to maneuver through each slalom based on normal driving). Participants were instructed to alternate passing to the right and left of the cones while maintaining a fixed speed. Three speeds were used: 15, 20, and 25 mi/h (24, 32, and 40 km/h). The researchers determined these speeds to be reasonable and safe based on speeds measured in the field. Following each pass through the slalom, the participants were asked questions such as these: How realistic was the feeling of moving through the slalom? How comfortable did you feel moving through the slalom? How controllable did the car feel while driving through the slalom? When asked about realism, comfort, and controllability, the participants' mean ratings were all above 5 on the 7-point scale, where 1 was low ("not at all realistic," "very uncomfortable," and "uncontrollable," respectively) and 7 was high ("very realistic," "very comfortable," and "easy to control," respectively).

The researchers also asked the participants whether they had experienced any false motion cues while driving through the slalom, such as slipping, sliding, spinning, or moving in the wrong direction. All of the participants indicated that they had not experienced false motion cues.

Making It "Feel Like The Real Deal"

Producing a driving simulation that mimics the exact perceptions that a motorist experiences while driving a car on the road remains a challenge. For instance, it is difficult to create the exact acceleration, deceleration, and turning forces that a driver feels while driving. However, through systematic and methodical tuning of driving simulators, researchers can optimize all significant functions for the best possible driver perception.

According to Monique Evans, director of FHWA's Office of Safety Research and Development, "ensuring that the driving simulator's motion base is finely tuned in order to increase the realism and validity of test results is crucial for performing valid experimental studies."

Although the results achieved for turning movements were not as favorable as those for acceleration, braking, and slalom testing, the researchers decided that the tuning process should focus mostly on acceleration and braking, because the next few planned experiments involve driving only on freeways. Further tuning of the turning motion was deferred until an experiment with navigation at lower speed roads is planned.

Another finding from this study is that the motion base is not always the root cause of false cues. The researchers found that modifying steering, accelerator, and braking algorithms also can help produce the best possible driver perceptions.

"Overall," says FHWA's Yang, "the systematic tuning process minimized the perception of false cues during simulated scenarios. And, this fine-tuning makes operating the highway driving simulator feel like the real deal."

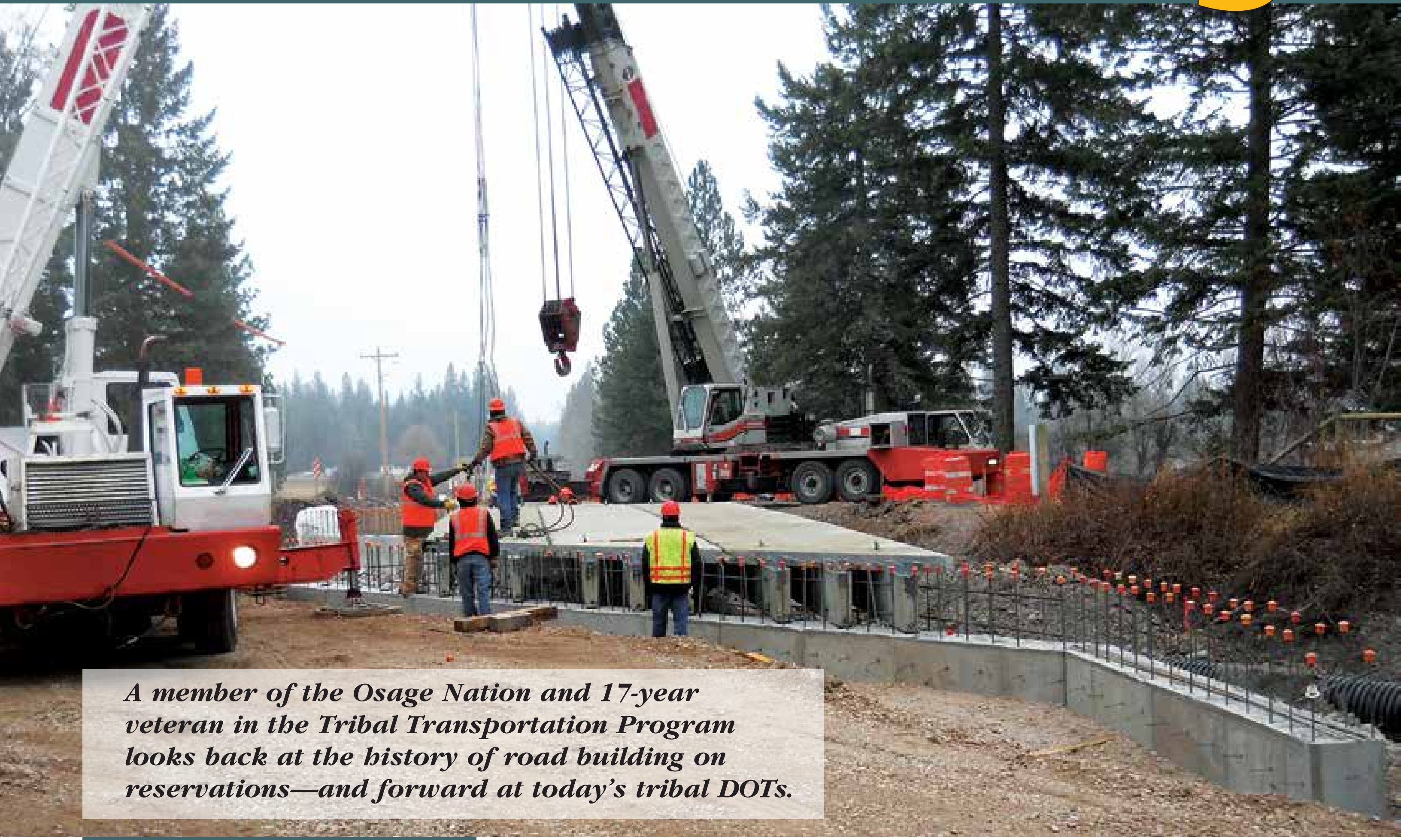
Barry Wallick, with Textron Systems Support Solutions, has been the program manager and principle systems engineer for FHWA's highway driving simulator at the Turner-Fairbank Highway Research Center since 2002. Wallick received a B.S. in electrical engineering at the University of Maryland and an M.S. in computer science at Loyola University Maryland.

Michelle Arnold is a transportation specialist on the Human Factors Team in FHWA's Office of Safety Research and Development. She received a B.S. in psychology and an M.A. and Ph.D. in applied behavior analysis from Western Michigan University.

For more information, please contact Michelle Arnold at 202-493-3990 or michelle.arnold@dot.gov.

A New Era Is Dawning

by Kyle Kitchel



A member of the Osage Nation and 17-year veteran in the Tribal Transportation Program looks back at the history of road building on reservations—and forward at today's tribal DOTs.

(Above) This tribal road construction crew is replacing a bridge on the Flathead Reservation in Montana. The department of transportation of the Confederated Salish & Kootenai Tribes employs an engineer, a planner, technicians, a construction supervisor, and a road maintenance supervisor. *Photo: Confederated Salish & Kootenai Tribes Natural Resources Department.*

The following question emerged 2 years ago at the Office of Federal Lands Highway and the Bureau of Indian Affairs: "How long has the Federal Highway Administration been working in Indian Country?" The reason for this question stems from the growing interaction among FHWA, tribal governments, the Tribal Transportation Program, and the Federal-Aid Highway Program's division offices. According to the 2013 audit by the Office of Inspector General, "One of the changes Congress has made to FHWA's role in the program is that tribes now have the option to carry out their transportation program directly through FHWA. The number of tribes opting to work directly with FHWA has increased from the initial 3 in 2006, to the current number of 117 tribes." As of September 2015, that number had grown to 130.

With roots back in roadway legislation enacted in the early 1900s and evolving out of more recent legislation, tribal public authorities have emerged across the country and are developing into full-fledged departments of transportation.

These tribal DOTs are working to improve the transportation infrastructure in Indian Country.

In Montana, for example, Dan Lozar, P.E., manager of the Division of Water of the Natural Resources Department of the Confederated Salish & Kootenai Tribes, says, "We are forced to contend with ever-increasing construction and maintenance costs while funding levels remain stagnant. A successful marriage between planning and engineering allows for our continued success despite this difficult situation."

He adds, "Transportation is truly a communal need. It's tough to find a more fundamental right than safe and efficient transportation on the reservation. We constantly think outside the box to make our projects go further, but a vast and aging infrastructure will forever keep us clawing uphill."

In other words, the tribal DOTs are facing the same financial challenges and constraints as State DOTs. Over the years, they have been addressing those challenges, and others.

Early Road Building On Reservations

Examples of road building can be found in treaties between Indian nations and the Federal Government. For example, the second article of the Treaty of Fort Laramie with Sioux, Etc., signed on September 17, 1851, reads, "The aforesaid nations do hereby recognize the right of the United States Government to establish roads, military and other posts, within their respective territories."

Another example is the third article in the treaty with the Yakima (now known as the Yakama Nation) in 1855: "And provided, that, if necessary for the public convenience, roads may be run through the said reservation; and on the other hand, the right of way, with free access from the same to the nearest public highway, is secured to them; as also the right, in common with citizens of the United States, to travel upon all public highways."

When the treaty era ended around 1900, reservation boundaries determined the locations of many Native American communities, and their previous way of life came to an end. A workforce-model society more reminiscent of Western civilization replaced the nomadic life of many tribes or other traditional ways of life. Governmental policies administered goods and services through Indian agents hired by the Federal Government for reservations and other areas of Indian Country.

A Federal law passed March 3, 1875, required that all able-bodied Indians between the ages of 18 and 45 had to labor for the benefit of themselves or the tribe in order to be entitled to rations. In 1885, U.S. Indian Agent R.H. Milroy reported from the Washington Territory: "I had the board to lay off the reservation into seven road districts, and to appoint a road supervisor in each, whom I instructed in their duties in relation to warning out the able-bodied men of their districts, opening and constructing roads and bridges, keeping the same in repair."

Road, river, and train transportation all figured in the 1900 report of the Commissioner of Indian Affairs: "All agency and school supplies, formerly brought in by steamboats, are now transported from [the town of] Needles, [CA], in large rowboats by the Indians. They also transport many tons of freight for mines along the river. A large number have worked in mines the past year, and in cutting wood and making roads for mines. The prospect for an increase of such work is good. A number are working for the Santa Fe Railroad Company, and a few on ranches. For the first time a number are earning good wages carrying mails. Practically all this outside work has been secured for them through the efforts of the agent and agency employees."

Any idea that some observers today might harbor to the effect that the Federal Government provided the necessities of life to the Indian people without their participation is erroneous. The laborers who built the homes and schools, farmed the land, and harvested the crops on reservations were a tribal workforce.

In addition, through various forms of government programs, Native Americans developed labor skills that enabled them to work off the reservation in mainstream U.S. society and to be assimilated into the workforce of Western society. Through those government programs, Indian road construction crews also began to emerge.

During this early period, the U.S. Government considered tribal citizens to be members of an aboriginal people, not members of a tribal government. The idea was to assimilate the individual Indian into becoming a U.S. citizen, not as a member of a tribal government that could manage a transportation project. This approach resulted in tribal citizens being allowed to participate in the transportation process as laborers, but not as decisionmakers or as administrators.

This would take time to change.

U.S. National Archives and Records Administration

This historical photo shows Indians working on the Milk River Project, the road to Sherburne Reservation in Montana, circa 1903.

Confederated Salish & Kootenai Tribes Natural Resources Department

The Confederated Salish & Kootenai Tribes constructed this road improvement project to access home sites on the Flathead Reservation.

The Transfer Legislation

During the early years of road building on reservations, the Federal Government supplemented the financial costs. According to FHWA's unofficial historian Richard F. Weingroff, the Federal Highway Act of November 9, 1921, rejected the view of long-distance road advocates who wanted the Federal Government to build a national highway network. Weingroff wrote, "To satisfy them, the act limited Federal aid to a system of Federal-aid highways, not to exceed 7 percent of all roads in the State."

Also included in this act under section 3 was the following: "The Secretary of Agriculture is authorized to cooperate with the State highway departments, and with the Department of the Interior in the construction of public highways within Indian reservations, and to pay the amount assumed therefore from the funds allotted or apportioned under this Act to the State wherein the reservation is located."

This 1921 legislation, as interpreted by the U.S. Comptroller General, spurred road work on Indian reservations with the Federal Government picking up the tab. Following this legislation, the Bureau of Indian Affairs approved access to these projects for approximately 25 reservations.

Road building requires a large investment of funds, and with the Federal Government paying for 100 percent of the cost on Indian lands, it did not take long for State governments to realize that building roads on reservations was less expensive than constructing State routes bypassing the reservations.

With this 1921 mandate for funding projects, Indian laborers continued to develop their skills in road construction and would further their opportunities during the Great Depression when the Civilian Conservation Corps was created to put U.S. citizens back to work.

At the time, John Collier was the Commissioner of Indian Affairs. He petitioned on behalf of Native Americans to form a Civilian Conservation Corps for Indian Country. It was called the Indian Emergency Conservation Work. This corps called for an educational element that would provide management and leadership courses for Native Americans. As the program was implemented, however, the educational aspect was overlooked, and the greater focus was placed on completing projects with speed and efficiency.

Indian Reservation Roads Program

In 1928 the Indian Reservation Roads Program was established authorizing the Secretary of Agriculture to cooperate with State highway agencies and the Department of the Interior to survey, construct, reconstruct, and maintain Indian reservation roads serving Indian lands. The relationship would last until the Federal Lands Highway program developed in 1982 under the Surface Transportation Assistance Act. During these times, road building was administered under memorandums of agreement that developed Federal policies between the Bureau of Indian Affairs, Bureau of Public Roads, and then eventually with FHWA.

In 1974—1 year before passage of P.L. 93-638 Indian Self-Determination and Education Assistance Act, the memorandum of agreement between FHWA and the Bureau of Indian Affairs allowed tribal leaders at the decisionmaking table as peripheral negotiators. Prior to 1974, the district engineer with the Bureau of Indian Affairs made the decisions and then submitted them to FHWA for approval.

The Transportation Equity Act for the 21st Century (TEA-21), enacted in 1998, represented the next important step in increasing the responsibility of the tribes. TEA-21 allowed tribal governments to become public transportation authorities. TEA-21 modified the Indian Reservation Roads Program to permit tribal governments to assume responsibility for implementing transportation programs on reservations using Federal Highway Trust Funds. Eventually, transportation departments overseen by the tribal governments began to develop out of that program.

The rulemaking for this and other provisions of TEA-21 was completed in June 2004. This new responsibility birthed the tribal DOTs that administer the development of transportation systems in Indian Country today.

The Emerging Tribal DOTs

Through the leadership of tribal governments, public authorities have focused on fostering and employing transportation professionals within their various ranks, and establishing DOTs that can deliver a quality product. Tribal DOTs range from a single individual on some reservations up to fully functioning transportation departments similar to State DOTs on others.


AVCP Transportation

These force account workers representing the Association of Village Council Presidents pose in front of the equipment they are using to construct a project on tribal land.

Through self-determination and self-governance, tribes have assumed responsibility for delivering the Tribal Transportation Program (TTP), formerly known as the Indian Reservation Roads Program. Under the TTP, tribes may elect to administer the program through several forms of agreements with the Bureau of Indian Affairs or FHWA's Office of Federal Lands Highway. The agreements allow the tribal governments to administer the program under their policies and procedures and in accordance with Federal regulation 25CFR170.

To date, almost every federally recognized tribe participates in administering the TTP in transportation planning and/or construction. This opportunity has enabled tribal DOTs to grow in professionalism and fill jobs that Federal employees once held. The new era of tribal transportation administration is developing quickly.

Moreover, additional changes are occurring nationally. The Transportation Research Board has a full standing committee called the Native American Transportation Issues Committee. In addition, the National Congress of American Indians has a transportation committee, and there is also an Intertribal Transportation Association. These organizations are just a sample of what has developed in a short time, not to mention local and regional organizations throughout the United States.

Standards for Tribal DOT Projects

If a tribal DOT receives Federal funding for a transportation project, the tribe is required to follow Federal regulations similar to those that govern the Federal-Aid Highway Program that States adhere to. But they must also follow any tribal laws that apply.

Every tribal DOT administering the TTP must develop a long-range transportation plan and a Tribal Transportation Improvement Plan (TTIP). This plan is restricted to projects that are financially constrained (that is, ones with funds that are reasonably available to be programmed into a TIP to complete the project) and are on the National Tribal Transportation Facilities Inventory, which is managed by the Bureau of Indian Affairs. FHWA's Office of Federal Lands Highway also must approve the TTIP.

Prior to construction, tribal DOTs must have the project's plans, specifications, and estimates (PS&E) stamped (approved) by a professional engineer who is registered in the State where the project will take place. The tribe is the approving public authority for the PS&E package. The package consists of stamped design, permitting, rights-of-way, and environmental documentation, along with any FHWA-approved design changes.

Tribes also must adhere to any additional permits or requirements that might not be included in a State transportation department's PS&E package, but are included in their own laws that govern the area where they have jurisdiction, even when the land is held in trust by the Federal Government. Some of these laws pertain to the environment, land, and infrastructure. For instance, some tribal governments manage fisheries that depend on water quality for their viability. During the development of road projects that are adjacent to bodies of water, the tribal DOT might be required to obtain permits necessitated by tribal laws that deal with fisheries or water quality, in addition to complying with the Federal laws.

The tribal DOT will advertise the projects according to tribal policies and procedures, as well as any Federal requirements. Once the contract is awarded, the tribal DOT manages the project in accordance with its quality assurance and quality control measures. A representative of FHWA or the Bureau of Indian Affairs then makes routine visits to the jobsite to provide assistance, stewardship, and oversight of program funds.

Spotlights on Tribal DOTs

The following are examples of tribal DOTs in action:

Confederated Salish & Kootenai Tribes. Located in northwest Montana, the Flathead Reservation comprises 1.3 million acres (526,000 hectares) with a transportation network of approximately 1,800 miles (2,897 kilometers). Depending on the location, ownership of the roads ranges from county to tribal, State, and Federal authorities.

The roads program is housed in the tribe's Natural Resource Department—Division of Water. A licensed professional civil engineer manages not only road construction, but also the department's other civil engineering duties. The transportation engineering staff consists of a road engineer, a professional planner, civil engineering technicians (American Concrete Institute certified), a construction supervisor, and a road maintenance supervisor, along with force account crews, who are direct employees of the tribal government. Projects can range from work on local streets and bridges to partnerships working on State highways.

The tribe has a tribal college that offers training and education for equipment operators. The tribal DOT employs some of the graduates during the summers and often allows the college to use small-scale projects as training opportunities for the students.

Association of Village Council Presidents. Located in Bethel, AK, the villages in this remote and isolated region encompassing 57,826 square miles (149,769 square kilometers) are accessible only by small plane or boat. Internal circulation routes and access to subsistence activities are what drive the transportation needs in the villages.

The tribal DOT of the Association of Village Council Presidents addresses those needs. The association established the DOT in 2008 when its 15 federally recognized member tribes united to address the lack of infrastructure, as well as unforeseen project needs in their villages. The department focuses on creating jobs, improving the quality of life of tribal members, and lowering energy costs in the region. It constructs all of its projects using a force account construction model to maximize economic benefits to the local economies.

What's Ahead?

To compete in a 21st-century transportation environment, tribal DOTs have had to adapt and learn a great deal in a limited time. They have gained the respect and admiration of the transportation community as it has witnessed their growth in self-determination and self-governance.

"The more than 565 federally recognized tribes are explicitly acknowledged as public authorities in 23 U.S.C. 101," says Robert W. Sparrow, director of the Tribal Transportation Program in FHWA's Office of Federal Lands Highway.

Gaining recognition as DOTs is an ongoing process that requires State and local DOTs to acknowledge that the tribal DOTs are full-fledged public authorities that have taken on the responsibility of sovereign nations for their own transportation systems.

Kyle Kitchel is the lead transportation specialist assisting the TTP. Based in FHWA's Office of Federal Lands Highway in Vancouver, WA, he is a member of the Osage Nation and has been working with the TTP for 17 years. He holds a B.A. in urban and regional planning from Eastern Washington University.

For more information, contact Kyle Kitchel at 360-619-7951 or kyle.kitchel@dot.gov.

These workers with the Association of Village Council Presidents are reconstructing an old boardwalk at Kongiganak, a coastal Alaskan village.

AVCP Transportation

Intelligent Transportation Systems (ITS)

ePrimer

Build your knowledge and expertise in ITS with a new, easy-to-use, FREE Web resource.

Photos courtesy of Thinkstock.

The *ITS ePrimer* provides transportation professionals, educators, students, and others with a series of up-to-date, Web-based modules describing key ITS topics, with a multimodal perspective.

- **Up-to-date, comprehensive information on ITS fundamentals**
- **Interactive Web links and videos**
- **ITS-focused modules and related slide presentations**
- **Free**
- **24-hour online access**

Web-Based Modules

- Introduction to ITS
- Systems Engineering
- Transportation Management Systems
- Traffic Operations
- Personal Transportation
- Freight, Intermodal, and Commercial Vehicle Operations
- Public Transportation
- Electronic Toll Collection and Pricing
- Supporting ITS Technologies
- Rural and Regional ITS Applications
- Sustainable Transportation
- Institutional Issues
- Connected Vehicles
- Emerging Issues

Keep pace with rapidly advancing transportation technology. Expand your knowledge at:

www.pcb.its.dot.gov/ePrimer.aspx

U.S. Department of Transportation

by David K. Hein,
Samuel S. Tyson, and David R. Smith

CONCRETE Turns Green, Figuratively Speaking

For minimizing stormwater runoff, permeable interlocking concrete pavements are increasingly popular. Learn here about their use, design, construction, and maintenance.

Early permeable pavements typically consisted of stone, concrete, or plastic pavers laid out in a grid pattern with soil and grass between the individual units. Although these systems increased permeability and permitted some rainwater to infiltrate rather than run off, they did not provide substantial structural capacity.

More recently, researchers and industry have designed permeable interlocking concrete pavements (PICPs) to accommodate more frequent and heavier vehicle loading. As a result, PICP applications have expanded to include streets, walkways, driveways, large commercial parking areas, alleys, and roadway shoulders.

A PICP consists of a surface of paving units with joints or openings filled with permeable aggregate. The joints allow water from storms to flow freely into an open-graded aggregate base or subbase reservoir that stores the water before it is released to aquifers, streams, and lakes. For soils with low infiltration rates, perforated drain pipes are often placed in the subbase or subgrade to drain excess water directly to storm sewers or to a surface water feature.

The new permeable interlocking concrete pavements not only have wider applications because they are stronger, but they also address a number of other issues, such as water pollution and excess heat in surface waters, which can be dangerous to aquatic ecosystems.

Varieties of Paver Systems

Concrete and clay brick pavers are available in a variety of shapes, and these generally conform to ASTM product standards. Some involve large paving elements with arched surfaces reminiscent of cobblestones. But the most common segmental types are PICPs consisting of solid concrete paving units that meet the size and concrete properties in

(Above) This alley in downtown Longmont, CO, is constructed of permeable interlocking concrete pavements (PICPs) bordered by a poured concrete pad that directs water from the roof drains toward the permeable paving units. *Photo: David Hein, ARA.*

ASTM C936 *Standard Specification for Solid Concrete Interlocking Paving Units*. When assembled into a pattern, they create joints or openings in the pavement surface.

The joints, which are filled with permeable aggregates, permit water to freely enter the subsurface at rates as high as 1,000 inches (2,540 centimeters) per hour. The paving units are compacted on a thin bedding layer of permeable aggregates, which rests over a base and subbase of larger open-graded aggregates.

In vehicular applications, the concrete pavers, bedding, and base layers are typically restrained by a concrete curb.

Geosynthetics such as geotextiles, geogrids, or geomembranes are applied to the subgrade, depending on the structural and hydrological design objectives. Separation geotextiles placed on the sides of the base and subbase prevent the entrance of fines from adjacent soils.

Benefits of PICPs

Like other permeable pavements, PICP systems typically are a component of a treatment train; that is, a series of control measures that infiltrate stormwater on a site and reduce water pollution. An example of a treatment train is a roof garden that drains stormwater into a PICP parking lot, and then overflows into a bioswale. Such designs that combine various control measures are a very effective approach to stormwater management.

When stormwater is treated through a PICP system, the water is filtered so that suspended particles are captured and held within the aggregate bedding, base, and subbase layers. Removing suspended particles from stormwater discharge benefits water quality by reducing attached heavy metals and nutrients that would otherwise enter streams or other surface waters.

Heavy metals such as copper and zinc are often attached to the suspended particles and are introduced into stormwater by weathering roofs, rusting vehicles, and brake linings. In sufficient quantities, these metals can be toxic to aquatic life.

Stormwater, in addition to containing heavy metals, often holds other suspended solids—plant litter, animal waste, and fertilizers—that carry nutrients such as nitrogen and phosphorus. These nutrients can cause excessive and ecologically harmful plant and algae growth in receiving water systems.

Research over the past 20 years, summarized by Eisenberg et al. in the American Society of Civil Engineers (ASCE) book, *Permeable Pavements*, has demonstrated that permeable pavements are an effective method for managing stormwater runoff and capturing pollutants from urbanized areas. Average design efficiencies for pollutant removal from water exiting PICP drains are on the order of 75 percent for total suspended solids, 45 percent for phosphorus, and as high as 40 percent for nitrogen. Permeable pavement systems typically treat oils through bacterial digestion and metals through adsorption to clay particles. Permeable pavements do not remove chemicals, salts, metals, or nutrients dissolved in the water, except by infiltration into the soil subgrade.

Excessive temperatures are another form of water pollution. During the warmer months, urban environments contaminate stormwater runoff with heat from rooftops and pavements. The thermal energy is conveyed through storm drains to receiving creeks, rivers, and lakes. This process can create sharp and rapid increases in water temperature, which is harmful, and sometimes toxic, to aquatic organisms.

Water retained in the reservoir layers within PICPs has an opportunity to cool down prior to its discharge. Water that infiltrates becomes part of the groundwater supply in the water cycle, further promoting natural temperature balancing.

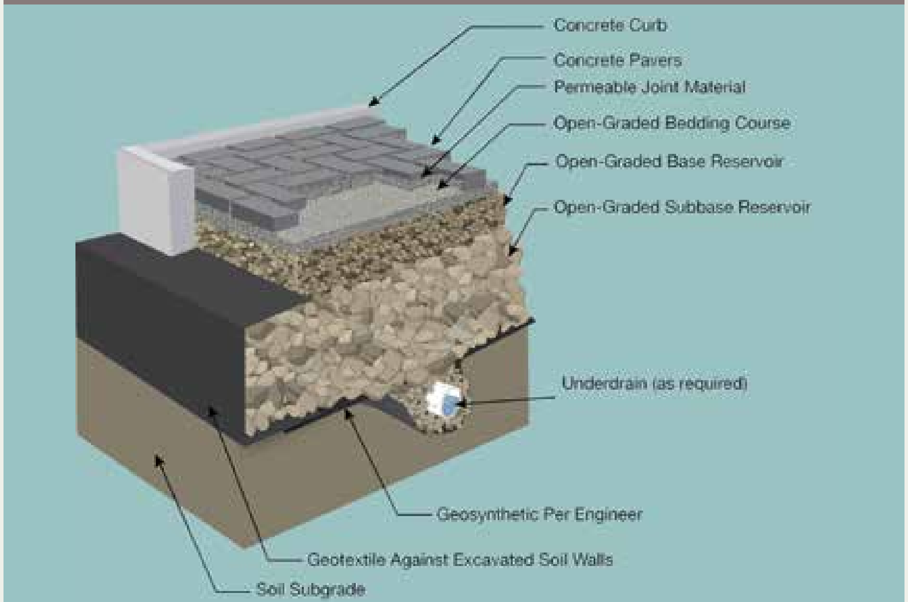
Another benefit of the use of PICPs in urban areas is that they may offer cost savings where they can conserve land use. They do not require land to be used for runoff detention facilities, and they reduce the need for space to install drainage infrastructure.

Compliance With Stormwater Regulations

PICPs can help achieve compliance with a number of national, regional, State, and local regulations, as well as design requirements for the control of stormwater runoff. These requirements can include implementing some of the following activities:

- Complying with National Pollutant Discharge Elimination System (NPDES) permits.
- Controlling runoff volumes and pollutants from new developments and redevelopments.
- Limiting impervious cover, such as roofs and pavements, as well as the resulting runoff.
- Reducing overflows, especially combined sewer overflows in older urban areas, by regulating the volume of runoff for storage and infiltration.
- Meeting the total maximum daily load requirements for receiving waters.

Cross Section of a Typical PICP



Source: Interlocking Concrete Pavement Institute.

Are PICPs Right for Your Next Job?

Site Feature	Considerations
Drainage Path	Assess drainage patterns in the surrounding area to determine possible impacts.
Traffic Type and Patterns	Assess the traffic type and composition. Avoid using in high-traffic areas subjected to repeated loading from buses or heavy trucks. Avoid use where traffic will contaminate the pavement surface with dirt, oil, and grease.
Winter Maintenance	Avoid the use of winter sand, which may clog the pavement. If sand is used, remove it the following spring.
Groundwater Depth	Avoid the use of PICPs in areas where the groundwater is within 2 feet (0.6 meter) of the bottom of the pavement subbase.
Subsurface Conditions	Underground utilities and the presence of bedrock may require special considerations. Utility lines in the base or subbase might require encasement.
Surrounding Land Use	Avoid use in areas where high levels of sediment or other contaminants are generated.
Rainwater Capture and Reuse	Limit the use of deicing chemicals or other contaminants where stormwater is captured for reuse.

- Complying with regulations that prescribe the capture and management of specified rainfall depths for improving water quality and reducing runoff volumes. Such regulations are typically expressed as a percentile (for example, 85th percentile or 95th percentile storm depth) as required for U.S. Federal Government facilities in section 438 of the Energy Independence and Security Act.
- Complying with building code requirements. Examples include the California Green Building Standards Code, the International Green Construction Code, American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 189.1, or other codes that require compliance with Leadership in Energy and Environmental Design (LEED®), Sustainable Sites Initiative™, or similar sustainable design and construction rating systems.

Determining Project Suitability

Permeable pavements are not suitable for every application. But with proper design, construction, and maintenance, they can provide a low-impact, green alternative worth considering.

Several key factors should be considered when determining whether a permeable pavement system is suitable for a given project. The key factors may not have equal weight relative to their impact on decisionmaking. Typical site characteristics to consider before using a PICP, or other permeable pavements, are the drainage path, traffic types and patterns, winter maintenance, groundwater depth, subsurface conditions, surrounding land uses, and rainwater capture and reuse.

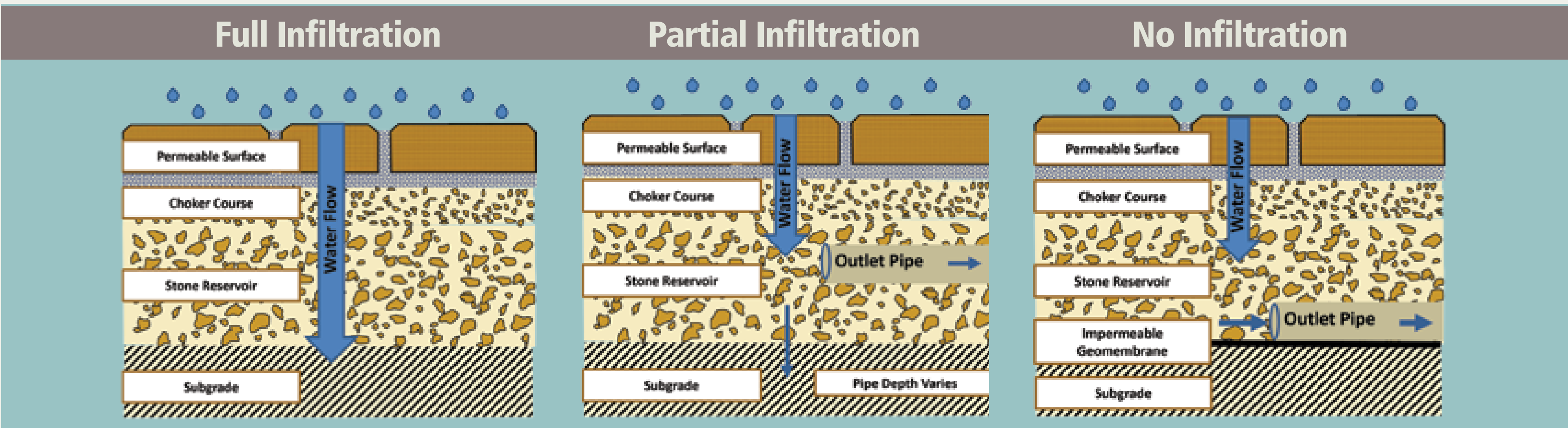
To assist in evaluating the suitability of projects for the use of permeable pavements, researchers developed a project suitability matrix. (See http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP25-25(82)_FR.pdf.) The matrix includes considerations such as flaws or major design challenges, that have an overriding influence on the decision to move forward with a project. These criteria provide an initial decision screening for the suitability of a site for permeable pavements.

The considerations are weighted the highest to reflect their importance in moving forward with the project. Secondary and other considerations are used to prioritize the suitability of sites but are not generally viewed as factors that remove permeable pavements from consideration. The decision factors are rated, and then the weighted factors are totaled on a scale of 0 to 100. If the score adds up to less than 65, the project is not considered to be a good candidate for permeable pavements. Between 65 and 75, the project can be considered. Scores greater than 75 indicate that the project is well suited for permeable pavements.

For example, the matrix was used to consider a total of seven urban locations in Berkeley, CA, that had suitability scores ranging from 47 to 67. The city eventually selected a section of Allston Way, a downtown street, for a demonstration project. The contractor excavated the existing pavement, which had reached the end of its service life. The workers removed the pavement to the subgrade level and installed a permeable subbase and base, followed by permeable interlocking concrete pavers. The city completed the project in the fall of 2014. Since then, the city has been evaluating the effectiveness of permeable pavements

ICPI

A suitability matrix led to the transformation of Allston Way in Berkeley, CA, from a worn-out conventional street to this attractive permeable interlocking concrete pavement.



Source: FHWA.

for stormwater management by monitoring outflows through drain pipes in the pavement. To date, only one outflow occurred from a severe storm. All other storms rendered no outflow, thus indicating infiltration into the clay subgrade.

Structural and Hydrological Design

Although there are many well-designed and constructed PICPs, some projects have performed below their design expectations. Therefore, implementing best practices for design, construction, and maintenance is essential.

The design of permeable pavements requires a balance between providing a structurally sufficient pavement to withstand traffic loading while achieving stormwater management and hydrological goals. Structural designers for conventional interlocking pavements and PICPs adopt the flexible pavement design procedures in the 1993 *Guide for Design of Pavement Structures* by the American Association of State Highway and Transportation Officials. The AASHTO design procedure is relevant because the load distribution and failure modes of PICPs are similar to those for other flexible pavement systems.

The design process includes an analysis of the expected axle loads, followed by characterization of subgrade strength and evaluation of the surface, base, and subbase thicknesses to support the design traffic for the life of the PICP. The structural capacity of the pavement layers in a permeable pavement system is lower than for conventional pavements. The open-graded nature of the surface, base, and subbase layers results in a lower structural capacity and structural layer coefficient than for conventional pavements. As a result, permeable pavements are generally thicker than conventional pavements for the same design traffic.

Hydrological analyses typically involve using a manual or a computerized model to characterize the movement of water through the pavement system under consideration. This includes water infiltrating into the soil subgrade, and outflow through underdrains. In general, hydrological analyses assess the extent to which water volumes can be stored and infiltrated over 48 to 72 hours, with the remainder released out of the pavement structure.

When PICPs are installed over high-infiltration subgrade soils, they may not require an underdrain. Such structures are called full-infiltration designs. Although water storage is available within open-graded aggregates, all of the stormwater that enters the PICP infiltrates into the subgrade until the system drains dry.

Partial-infiltration designs are used where subgrade soils have low infiltration rates. Such soils make it impossible to infiltrate all of the stormwater into the soil within a reasonable period of time, especially during extreme storm events. In these cases, an underdrain is included through which excess water discharges to a surface water feature or underground stormwater collection system. These drains often have raised outlets to detain and infiltrate some water into the soil and then release the remainder.

No-infiltration systems are designed to prevent infiltration into the soil subgrade. This is done for PICP systems installed over expansive or fill soils, or close to buildings, by enclosing the bottom and sides of the pavement structure with geomembrane (that is, an impermeable liner). An outlet pipe penetrating the membrane provides temporary storage and outflow control. This design approach also can be used for water harvesting or for horizontal ground-source heat pumps.

Construction Considerations

Construction techniques and proper maintenance also are critical to the longevity of permeable pavements. Permeable pavement materials are similar to those used for the construction of conventional pavements. The majority of the tests required to determine quality are also the same, except that compliance targets and minimum and maximum values differ.

Similarly, PICPs are manufactured using the same materials as traditional interlocking concrete pavers and do not require onsite curing time, nor are they subject to onsite variability in material mixes. To make the surface permeable, the manufacturer produces paving units with small spacer bars to create widened joints filled with permeable aggregate that permits water to enter.

Some key construction activities essential to the success of all permeable pavements include the following:

Preconstruction Meeting. A preconstruction site meeting is critical to installing permeable pavements successfully. All contractors and tradespeople must

David Hein, ARA

This sloping, unvegetated landscape allows the soil to wash onto the surface of the pavement and contaminate the paver joints.

David Hein, ARA

Here, landscaping materials, such as topsoil and wood chips, are piled on tarps placed on the surface of the permeable pavement. This approach is an example of good protection of the PICP during construction.

understand how to install the permeable pavement correctly and protect it from damage and contaminants during construction.

Subgrade Preparation. To facilitate water infiltration, guidelines published by State stormwater agencies for the construction of permeable pavement generally recommend not compacting the subgrade. Although an uncompacted subgrade benefits water infiltration, it tends to consolidate when saturated under vehicular loading, causing settlement and possible rutting of the pavement surface. Therefore, the design may need to balance infiltration against compaction.

The design engineer should conduct Proctor compaction tests in a laboratory, and then establish test areas for compaction of the in situ subgrade, followed by infiltration tests. This approach establishes a relationship between soil subgrade density and infiltration, and indirectly the strength of the soil subgrade, in order to sustain traffic loads when saturated.

In addition, the contractor should complete subgrade preparation during dry weather conditions. The contractor also should complete placement and compaction of the open-graded aggregate base and subbase as close together in time as possible to minimize the risk of sedimentation from construction vehicles or nearby erosion. If severe, such sedimentation can compromise water storage and infiltration into the soil subgrade.

Compaction of the Base/Subbase Aggregate Layer. Compaction of the open-graded aggregate is required for all applications. The compaction provides a stable platform for the placement of the surface course, as well as structural capacity for traffic support and prevention of settlement. A 10-ton (9-metric-ton) dual or single vibratory smooth drum roller or a reversible vibratory plate compactor delivering 13,500 pounds (60 kilonewtons) of centrifugal force with a compaction indicator is recommended. Stiffness measurements of the compacted base and subbase aggregates can be accomplished using a lightweight deflectometer used

David R. Smith, ICPI

(Left) This construction worker is compacting an open-graded aggregate base in a parking lot using a plate compactor that is too small for the size of the project. A roller compactor would be more efficient.

David R. Smith, ICPI

(Above) A worker is using a large, vibratory smooth drum roller to compact the open-graded aggregate base on this roadway. The equipment is appropriately sized for the job.

David Hein, ARA

Here, a construction worker is unrolling an impermeable geomembrane liner between curbs that separate soon-to-be-built permeable pavement parking areas from the adjacent roadway and sidewalk. Once the aggregate is installed, the crew will push the membrane down into contact with the soil.

according to ASTM E2835 *Standard Test Method for Measuring Deflections Using a Portable Impulse Plate Load Test Device*.

Geotextiles. For all applications, these materials are generally placed vertically against the walls of excavated soil to separate the permeable pavement from adjacent soils. Geotextiles are typically nonwoven fabric, and the contractor should protect them from contamination during installation. This is done by keeping equipment from traversing the fabric and preventing sediment from entering the excavated area.

Geomembranes. Typically composed of polyvinyl chloride, ethylene propylene diene monomers, or high-density polyethylene, geomembranes may be used to vertically separate the open-graded base and subbase from adjacent pavements and building structures. Since these materials are impermeable, they prevent water from entering building foundations. In other cases, they may enclose the sides and bottom to create a no-infiltration design for water storage and flow control.

Drainage Features. Depending on the drainage design goals for the permeable pavement, perforated drainage pipes may be used to convey stormwater from high-flow rain events away from the pavement. Other drainage features, such as drain inlets, curb cutouts, and additional subsurface piping, may be designed to accommodate some of the surface or subsurface water flow during significant storms.

Underdrains. The contractor should install a perforated underdrain, if required, in a trench at the lowest point of the permeable pavement subgrade. The pipe is surrounded with open-graded aggregate that offers protection during construction. The underdrain pipe should have a minimum 2 percent slope to an outlet. The designer should select the pipe size and spacing to ensure that the pavement does not flood and become completely saturated during storms, because this can lead to instability and damage under vehicular traffic.

Supplementary Surface Drainage Features. Outlet pipes should not be perforated. Depending on the hydrological design goals for the project, the end of the outlet pipe may be upturned to promote water storage in the aggregate reservoir, increase infiltration, and reduce outlet flow. This is particularly useful for achieving detention (volume capture) objectives. Pipe outlets should be directed to outlet chambers or other protective systems to prevent soil erosion.

Observation Wells. These features typically consist of a perforated plastic pipe placed vertically through the pavement and anchored into the subgrade. They are installed to enable maintenance crews to observe or measure downward drainage over time. Such wells can function as places to remove accumulated sediment if required.

Other Keys to Success

Other important factors for successful installations include the following:

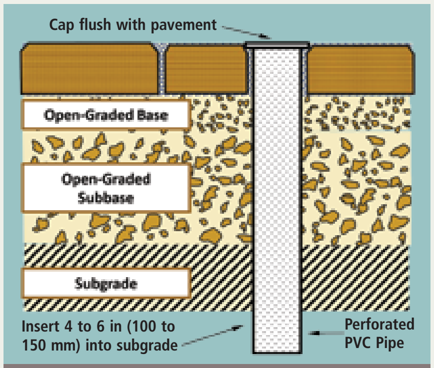
Edge Restraints. One key element is edge restraints to prevent lateral movement of the surface during construction and under traffic. Edge restraints consist of concrete curbs, adjacent pavement surfaces, dense-graded aggregate base (protected by a geomembrane), or landscape architectural features. Edge restraints are particularly important for permeable shoulder applications for vehicles traversing on a shoulder to the traveled lanes. Vehicle wheel loading near an unsupported edge might damage the permeable pavement.

Mechanical Installation. Most PICP projects are machine installed to accelerate construction time while reducing labor costs. An experienced machine operator typically lifts and places about 1 square yard (0.8 square meter) of PICP every 20 seconds, setting it on the screeded bedding layer in its final pattern. This installation rate can be three to five times faster than manual installation. The paving units are compacted, the joints are filled with aggregate, and the paver surface is swept clean and compacted again.

Contractor Certifications and Experience. The production and placement of permeable pavements generally require attention to detail to ensure that a durable pavement is produced. In addition, contractors and tradespeople working at or near the permeable pavement must be cognizant of the need to avoid clogging the pavement surface and joints with particles. Avoiding surface clogging may require the installation of cattle guards and tire washing stations to ensure that the

This nonperforated polyvinyl chloride pipe outlet is surrounded by riprap aggregate to protect the soil from being eroded by water leaving the pipe.

David Hein, ARA



Observation wells like the one in this diagram consist of a perforated plastic pipe placed vertically through the pavement and anchored into the subgrade. *Source: David Hein, ARA.*

construction traffic does not contaminate the pavement with sediment. For training and certification, the Interlocking Concrete Pavement Institute (ICPI) offers a 1-day PICP specialist course that earns a record of completion. Contractors who take an additional certification course and provide evidence of at least 50,000 square feet (4,645 square meters) of PICP installation experience and continuing education qualify for ICPI Certified Installer and PICP Specialist designation.

Maintenance Inspections

Transportation departments should conduct PICP inspections once or twice annually (preferably after a storm event). Inspection tasks need to include the following:

- Review maintenance and operations records to determine indicators of the need for maintenance.
- Document general site features and take photographs of the pavement.
- Note obvious sources of surface contaminants, such as sediment.
- Identify the extent and severity of any damage or deficiencies (for example, settlement, ponding, and cracked pavers). Document the structural condition and create a pavement condition index using ASTM E2840 *Standard Practice for Pavement Condition Index Surveys for Interlocking Concrete Roads and Parking Lots.*
- Identify any changes in adjacent land use that might affect runoff from the contributing area, creating potential sources of contaminants that could reduce system permeability.
- Inspect vegetation around the PICP perimeter for cover and soil stability.
- Inspect edge restraints to ensure continued functioning.
- Repair or reinstate damaged edge restraints to correct the resulting movement in the pavers. Repair may require the removal and reinstatement of adjacent paving units.
- Check the observation well(s) and outlet drain(s) to ensure continued water drainage from the pavement structure.
- Check the surface for buildup of sediment in joints. Buildup typically occurs at locations nearest the adjoining impervious pavements.
- If surface water remains longer than 1 hour after a rainstorm, then conduct the ASTM C1781 *Standard Test Method for Surface Infiltration Rate of Permeable Unit Pavement Systems* to determine the surface infiltration rate.
- Repair localized settlement greater than 0.5 inch (13 millimeters [mm]) and rutted pavement areas.
- Repair outflow features, piping, energy dissipaters that reduce and spread water flow, and erosion protection systems, as required.

The transportation agency should document the results of the inspection to assist in updating the maintenance plan for the PICP system, as well as develop a database of maintenance to meet any NPDES permit requirements. This information should assist in predicting future maintenance needs and can be part of an overall management system for the pavement. Based on the results of the inspection, it may be appropriate to conduct remedial maintenance, particularly if the surface has not been vacuumed regularly.

If the results of the ASTM C1781 test are below 10 inches per hour (254 mm per hour), vacuum the

Shown here is a PICP sidewalk and parking lot. The red circle indicates the location of a well cap on the surface of the sidewalk.

Richard Woodbam, Weston Solutions, Inc.

David Hein, ARA

This curb restrains the paving units while the cutout enables excess runoff from the surface of the PICP (foreground) to flow into the vegetated bioswale for additional treatment should the PICP overflow in a severe rainstorm.

David R. Smith, ICPI

A worker is using a machine with a mechanical arm to lift a layer of interlocking concrete pavers from a pallet and place them in the final laying pattern onto an aggregate bedding.

surface to remove sediment trapped in the joints (typically 0.5 to 1 inch, or 13 to 25 mm, deep) using a full or true vacuum machine (not regenerative air). Refill joints with clean aggregate, sweep the surface clean, and test the infiltration rate again per ASTM C1781 to a minimum 50 percent increase or minimum 10 inches per hour (254 mm per hour).

Winter Maintenance

Avoid the use of winter sand for traction. If used, remove with regenerative air cleaning equipment in the spring (regenerative equipment does not evacuate jointing materials):

- Remove snow with a standard plow or snowblowing equipment.
- Stockpile plowed snow onto turf or other vegetated areas and not on the PICP.
- Monitor temperatures and apply anti-icing or deicing materials such as sodium chloride, calcium chloride, or magnesium calcium acetate.

Performance

A substantial number of PICP projects can be found in parking areas, alleys, and roadways, as well as unusual uses of PICPs subjected to heavy loadings by buses and even military tanks. Pavement stability and winter durability of PICPs have been documented in parking lots in Toronto, Ontario, Canada; Chicago, IL; and Vancouver, WA. In addition, municipal DOTs in Los Angeles and Sacramento, CA; Longmont, CO; Washington, DC; Dubuque, IA; St. Louis, MO; Lancaster, PA; and Richmond, VA, have experience with PICPs in alley projects. PICP streets in Berkeley, CA; Atlanta, GA; Charles City and West Union, IA; Moline, IL; Lafayette, IN; and Winchester, VA, have integrated roadways with stormwater management, thereby solving stormwater problems in a cost-effective manner.

David Hein, ARA

This PICP next to a vegetated bioswale is installed in a parking lot near Portland, OR.

Summary

Permeable pavements can be a major contributor to the effective management of stormwater. They provide the opportunity to transform traditional stormwater management into use of a best management practice for capturing, storing, and infiltrating stormwater into the natural surroundings. The benefits include reduced stormwater discharges, as well as improvements to water quality, such as reduced suspended solids and chemical contaminants. Although permeable pavements can be an effective tool, engineers should carefully consider structural and hydrological concerns in their design and construction to ensure that these systems provide cost-effective solutions over their design life.

David K. Hein, P. Eng., is vice president of transportation at Applied Research Associates, Inc., in Toronto, Canada. He chairs a committee of the American Society of Civil Engineers (ASCE) that is developing a consensus standard for the design, construction, and maintenance of PICPs. He holds a bachelor of applied science degree from the University of Waterloo in Canada.

Samuel S. Tyson, P.E., is a concrete pavement engineer with the Federal Highway Administration's Office of Asset Management, Pavements, and Construction in Washington, DC. He earned a bachelor's degree in civil engineering and an M.S. in civil engineering from the University of Virginia.

David R. Smith is the technical director of the Interlocking Concrete Pavement Institute in Chantilly, VA. He holds a master's degree in urban and regional planning (environmental concentration) from Virginia Tech. He has written a book on PICPs and has contributed to several Federal, State, and municipal guidance documents on permeable pavements, as well as the ASCE book, *Permeable Pavements.*

For more information, see the FHWA Tech Brief at www.fhwa.dot.gov/pavement/concrete/pubs/hif15006.pdf or contact David Hein at dhein@ara.com or 416-621-9555.

Connecting the Employment Dots

by Clark Martin

FHWA has established five new regional centers to help develop, recruit, and retain a highly effective transportation workforce, especially crucial given so many baby boomer retirements.

(Above) These workers are using accelerated bridge construction techniques to install an innovative, post-tensioned, precast concrete panel on a concrete girder in Minnesota. Properly maintaining and improving the Nation's transportation system requires a highly skilled workforce.

For the U.S. transportation community to deliver and manage an efficient, safe, and effective transportation system, it must have a highly capable workforce. Public and private transportation organizations are facing numerous workforce challenges, including an increasing number of workers preparing for retirement; new technology, procedures, and processes; competing demand for workers in other industries; aging transportation infrastructure in need of repair or modernization; increasing demand for transportation capacity; and constrained resources. To address critical issues in workforce recruitment, training, and retention, a number of key stakeholders must come together in a coordinated effort.

"The ability to modernize and improve the efficiency of the Nation's surface transportation network in today's global marketplace requires a skilled and innovative workforce," says Pete Ruane, president and CEO of the American Road & Transportation Builders Association. "We will rely on this workforce to properly build and manage long-overdue repairs and projects that add transportation capacity."

The solution in a nutshell? In 2014, the Federal Highway Administration established five new regional centers focused on workforce development.

Workforce Challenges

More than 50 percent of the transportation workforce will be eligible to retire in 10 years. This will create not only a significant loss of specialized knowledge and experience, but also a need to train a new generation of young workers and leaders. New professionals will have to enter transportation from other fields, and younger skilled workers already in the field will have to fill openings left by their experienced, retiring predecessors.

In addition to a high rate of retirement and vacancies in this field, emerging technologies are changing the knowledge base and skill requirements for future workers. More complex operating systems require skilled high-tech operators. New technological competencies are essential to foster the rapid increase in innovation in transportation planning, development, and system management.

Given these challenges, transportation, education, and labor organizations share common workforce concerns: Will the next generation of transportation workers be prepared to develop, design, construct, operate, and manage the Nation's transportation system in the face of increasing transportation demand? Does the current transportation workforce have the skills, knowledge, and ability to be efficient in their work, including understanding changing policies and programs and using new technology? Is the current and future workforce equipped to provide for a transportation system that will help ensure that the Nation can compete in increasingly competitive international markets?

"To address the workforce needs of a wide range of employees in the 21st century," says Acting Assistant Secretary Johan Uvin of the Office of Career, Technical, and Adult Education at the U.S. Department of Education, "we must ensure that they are well equipped in using changing technology and have the knowledge and skills to compete in a global economy."

To do so, transportation, education, and labor organizations must coordinate and leverage their workforce development resources effectively.

Workforce Development

"Transportation is a high-demand industry that provides excellent opportunities for good jobs with good wages," says Eric Seleznow, deputy assistant secretary, Employment and Training Administration, U.S. Department of Labor. Workforce development programs must ensure that the public is aware of those opportunities.

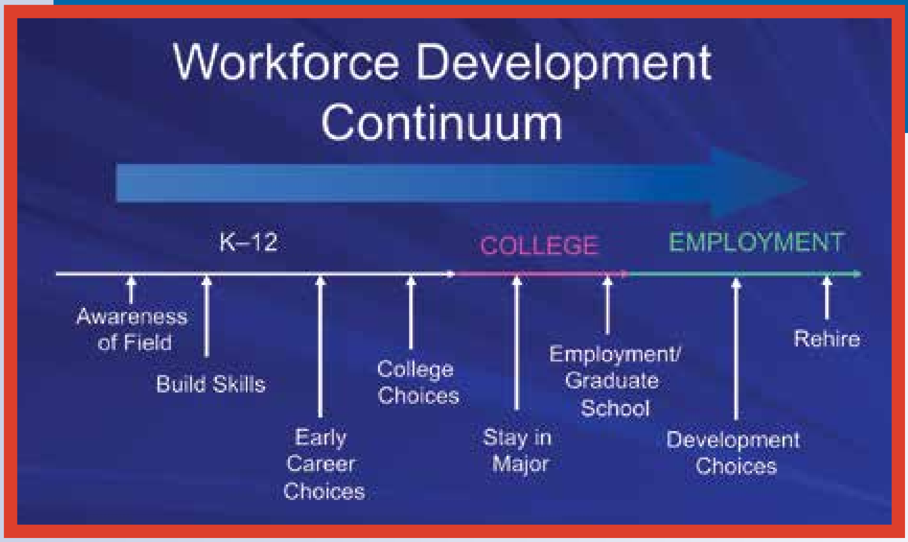
Education and industry need to work together to support career pathways for current and future transportation workers. Pathways into the field vary. Some start when exposure to transportation studies in school piques a student's interest, or when an entry-level professional decides to take a transportation job, or when experienced workers realize that they can apply their current knowledge, skills, and abilities somewhat differently within the transportation sector and so transition into that branch of the field. Transportation workers—engineers, planners, traffic technicians, logistics professionals, commercial drivers, equipment operators, and others—who design, build, manage, and maintain the Nation's highways, ports, and intermodal facilities have specific skills and therefore require specific training and education.

Thus far, public and private organizations have struggled to understand and address the needs of transportation workforce development in a structured manner that fits within existing programs. This issue is mostly due to the lack of an integrated, strategic plan and related tools among isolated transportation, education, and labor programs.

The first step in building a cohesive strategy is to consider the workforce development continuum, which starts with outreach to increase awareness of the transportation field and the development of skills during K–12 education. Next in the continuum is early career preparation and technical training at the college level, and then ongoing professional development maintained during employment. In addition, some workers retire from career positions and then are rehired in the transportation industry after retirement.

Building and raising career awareness. Building awareness and interest in transportation careers starts in school. Workforce programs can develop targeted outreach efforts in collaboration with K–12 schools, community colleges, and universities to encourage careers in transportation. Educational institutions can focus on building competencies to enable future workers to enter transportation careers better prepared, or to help current workers perform with greater effectiveness and efficiency.

For community college and university students transitioning from the classroom to the workforce, educators should collaborate with



Regional Transportation Workforce Centers

Northeast Transportation Workforce Center
University of Vermont
Glenn McRae, Director
glenn.mcrae@uvm.edu
www.netwc.net
Region: Connecticut, Delaware, District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont.
Focus areas: Disadvantaged youth, climate change, alternate fuels, and community colleges.

Southeast Transportation Workforce Center
University of Memphis
Stephanie Ivey, Director
ssalyers@memphis.edu
www.memphis.edu/setwc
Region: Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, West Virginia, and Puerto Rico.
Focus areas: Women in transportation, freight (including rail, truck, warehousing, and logistics), and military/veteran transition to the workforce.

Midwest Transportation Workforce Center
University of Wisconsin–Madison
Teresa Adams, Director
adams@engr.wisc.edu
http://mtwc.org
Region: Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Ohio, and Wisconsin.
Focus areas: Infrastructure, construction, planning, inland waterways, sustainability and environment, STEM (science, technology, engineering, and mathematics), and stackable credentials, which an individual accumulates over time to build his or her qualifications.

Southwest Transportation Workforce Center
California State University, Long Beach
Tom O'Brien, Director
thomas.obrien@csulb.edu
www.ccpe.csulb.edu/SWTWC
Region: Arizona, California, Colorado, Nevada, New Mexico, Oklahoma, Texas, and Utah.
Focus areas: Gateways and corridors, non-native English speakers, portability of skills, traffic management, and intelligent transportation systems.

West Transportation Workforce Center
Montana State University
Steve Albert, Director
stevea@coe.montana.edu
http://wrtwc.org
Region: Alaska, Hawaii, Idaho, Montana, Nebraska, North Dakota, Oregon, South Dakota, Washington, and Wyoming.
Focus areas: Rural transportation and safety, mobility and livability, tribes, and Federal lands.

public and private stakeholders to match curricula with the needs of the transportation industry and to increase the portability of transportation degrees, skills, and experience. Educators and employers also should expand the transportation workforce's access to post-secondary education.

Retention and continuing education. Once workers are recruited into the field, employers can take several steps to increase retention, such as offering incentives and benefits programs, recognizing good performance, encouraging a healthy work-life balance, and providing opportunities for advancement. Employers also can help their workforce adapt to technological advances in the industry by providing training and opportunities for professional development. They can plan for succession in the workforce through leadership development programs and performance management practices, such as annual performance appraisals, individual development plans, cross-training, and continuous communication between supervisors and employees.

Regional Transportation Workforce Centers

In collaboration with the U.S. Departments of Labor and Education, FHWA has established five regional transportation workforce centers to enhance transportation workforce development more strategically and efficiently. These five regional centers collaborate to form a national network for sharing workforce strategies and promising practices.

The centers, which are managed at universities selected through a competitive award process, help connect jobs with transportation needs. They create, coordinate, and facilitate partnerships with State departments of transportation and education, industry, and other public and private stakeholders to enhance transportation workforce development throughout the education continuum. The centers facilitate activities in Grades 6 through 12, and training in technical schools and community colleges, universities, and post-graduate programs, as well as professional development services for incumbent transportation workers.

"FHWA has made strategic investments to advance transportation workforce development," says Glenn McRae, director of the Northeast Transportation Workforce Center, one of the five centers. "Those investments are working, but in isolated ways. I think we have an opportunity to pool resources across sectors and industries to create a one-stop shop for workforce development."

The centers serve employers in the transportation sector, as well as individuals who would like to either enter the field or advance an established career. They also serve supporting education and labor organizations that recruit and direct people to the right resources.

"If you're in the transportation industry and want to be more involved in workforce development," says Teresa Adams, director of the Midwest Transportation Workforce Center, "or an educator who needs materials to help introduce transportation in your courses, or a student who wants to learn more about transportation careers, contact us."

The centers also will take inventory of existing transportation workforce development programs, stakeholders, educators, and employers in each region, and then form a supportive network of resources across the Nation. This inventory will involve identifying regional transportation job needs and priorities, cataloging existing workforce

Steve Albert, director of the West Transportation Workforce Center, showcases the center's resources.
Photo: Steve Albert.

Dr. Stephanie Ivey, director of the Southeast Transportation Workforce Center (standing, right), and two college mentors (standing, left and seated at far right) discuss vehicle design with high school students in the Girls Experiencing Engineering program at the University of Memphis, Herff College of Engineering. Activities like this help students better connect science and math principles with engineering design, which program staff then relate to the work of transportation engineers. *Photo: Stephanie Ivey.*

development and educational programs, and evaluating existing programs for scale and replication. The inventory also will involve pinpointing educational and training gaps, developing resources to bridge identified gaps, and fully engaging in the national network to showcase successful programs and practices, and to increase the impact in each region.

"The mission is really to act as a broker," says Steve Albert, director of the West Transportation Workforce Center. "We want to bring organizations together to add value to their workforce development programs through greater coordination and collaboration across the transportation, education, and labor communities."

Workforce Focus Areas

To understand and address the needs of a broad and varied transportation workforce, each center has chosen focus areas for which it will identify key organizations, issues, programs and activities, challenges, and best practices, and will serve as a resource for other centers and stakeholders. Each center selected its focus areas based on specific research concentrations at its host university, the particular interests and expertise of its director and staff, and priority workforce areas defined by FHWA.

For example, the Southeast Transportation Workforce Center is focusing on women in transportation, freight, and military veterans' transitions to the workforce. These subject areas are well suited for the center's director and staff. Director Stephanie Ivey is also director of the Center for Advancement of Female Transportation Professionals and program director for the University of Memphis, Herff College of Engineering's targeted outreach programs—Girls Experiencing Engineering and Transportation Engineering Careers. The center's research and data coordinator, Annie Wise Rapalo, also helps coordinate the Girls Experiencing Engineering program, and she is the organizational leader of the Society of Female Transportation Professionals in the Memphis, TN, area. The focus on freight is appropriate for both Private Sector Coordinator Dan Pallme and Public Sector Coordinator Sean Ellis, who serve as the current director and associate director, respectively, of the Intermodal Freight Transportation Institute at the University of Memphis..

The focus on veterans' transition to the workforce is particularly important as soldiers conclude their military service and return to the civilian workforce. Some transportation jobs in the military, such as heavy vehicle operation, logistics, and distribution jobs, relate well to similar jobs in civilian transportation. The southeast center will provide resources to help facilitate these transitions.

Looking Ahead

The transportation workforce is as varied, diverse, and complex as the transportation system itself. Transportation workers include planners, engineers, environmental specialists, safety practitioners, traffic operations managers, heavy equipment operators, financial specialists, technicians, and others in hundreds of occupations, all with varied skills, abilities, and levels of training and education. These workers serve public and private organizations, large and small, at the national, State, and local levels. They abide by specific policies and regulations, using technology and processes that may vary from one organization to the next.

Each of the more than 12.5 million transportation workers entered the field due to a unique set of experiences. All contribute to the efficiency, effectiveness, and safety of the U.S. transportation system, which facilitates a strong economy through access to goods and services and builds healthy communities through access to jobs and recreation.

Developing and maintaining an effective transportation workforce requires a coordinated effort by the transportation, education, and labor communities. Members of these communities are encouraged to contact their regional workforce center to engage in efforts to help build a strong workforce now and in the years to come.

Clark Martin is team leader of affiliate programs in FHWA's Office of Technical Services and FHWA manager of the Regional Transportation Workforce Centers. Martin has a B.S. degree from the University of Maryland, where he studied government, politics, and business administration.

For more information, visit the Regional Transportation Workforce Center Web sites listed on page 24 or contact Clark Martin at 703-235-0547 or clark.martin@dot.gov.

by Frank Jalinoos

Reusing Bridge Foundations

Some owners are building on existing elements when widening and replacing structures. Here is how this strategy can help expedite construction, minimize site impacts, and address sustainability needs.

(Above) The Indiana Department of Transportation and the Kentucky Transportation Cabinet used accelerated bridge construction and a prefabricated bridge system (a lateral slide) to rehabilitate the Milton-Madison Bridge between Milton, KY, and Madison, IN. Crews reused and strengthened the existing foundations, and then replaced the superstructure with a preassembled steel truss. *Photo: Courtesy of the Milton-Madison Bridge Project.*

Motorists cross bridges every day, sometimes multiple times a day, without giving it a thought, or even realizing that they are crossing a bridge, especially when it spans dry land. Bridges are such an integral part of today's transportation network that it is easy to take them for granted. However, bridge owners must periodically assess these structures to ensure the safety of the traveling public, and to make decisions regarding the maintenance and operation of their bridges.

A critical component of bridge owners' decisionmaking is the ability to characterize the foundations of bridges over both dry land and waterways. They then can use this information as part of the process for determining whether they should rely on the existing foundations to continue to carry increasingly heavy loads and to be resilient to geotechnical and hydraulic hazards, or whether they should consider major rehabilitation, replacement, or widening of a bridge.

But the characterization of bridge foundations is complex. Bridges may be supported by shallow or deep foundations of varying geometries and materials. The foundation elements range in size, shape, material, and construction. In addition, design or as-built drawings of foundations are not always available, resulting in a population of bridges with missing plans (or "unknown foundation" bridges). Plus, technologies for determining foundation condition are expensive and sometimes unreliable. The Federal Highway Administration is researching methods to clarify and mitigate these issues.

In 2013, FHWA approved a new multiyear strategic research program for the characterization of bridge foundations. To narrow the focus of the program and to solicit input from key stakeholders, FHWA held a workshop in Arlington, VA, from April 30 to May 1, 2013. The workshop identified the engineering problems associated with characterizing foundations, including assessing foundation type, pile type, embedment depth, geometry and material, foundation integrity, and load-carrying capacity. The workshop also focused on changes related to structural loading demands and foundation reuse issues from the perspective of FHWA and State departments of transportation. For more information, download the *Characterization of Bridge Foundations Workshop Report* (FHWA-HRT-13-101) at www.fhwa.dot.gov/publications/research/infrastructure/structures/bridge/13101/13101.pdf.

FHWA used the knowledge garnered from the workshop to establish the roadmap of its new Foundation Characterization Research Program. This research program's objectives are to develop and evaluate new and existing methodologies for characterizing bridge foundations to determine unknown geometry, material properties, integrity, and load-carrying capacity.

Engineering Application Areas

The Foundation Characterization Research Program supports identified needs in three engineering application areas: geotechnical and hydraulic hazards, changes in current loads, and foundation condition assessments.

In the area of geotechnical and hydraulic hazards, a foundation's vulnerability to scour and seismic events are of particular concern for the population of bridges with unknown foundations. Another concern is the post-event assessment, particularly evaluation of foundations after flooding, hurricane, seismic, or impact forces.

The Foundation Characterization Research Program is also looking into the impacts that current loadings have on foundations. Over time, changes in design code and regional and local needs can result in increased loading conditions that are different from the original design intent. This is particularly important when bridge owners are determining whether to reuse existing foundations in bridge replacement, widening, or rehabilitation projects. Further, characterization is imperative for making decisions about whether oversized, particularly overweight and routinely permitted, truck loads can cross bridges safely.

The third area of research under this program, foundation condition assessments, addresses the concerns related to degradation, decay, and long-term or inservice performance of substructure materials. Substructure materials can include timber, masonry, steel, and concrete.

Foundation Reuse

Of all the engineering application areas, foundation reuse is of particular interest to State DOTs and bridge owners. Reuse of bridge foundations often is needed when the replacement, rehabilitation, or modification of the existing bridge superstructure is required.

In support of recommendations from the foundations workshop in 2013, several follow-on workshops and sessions on the topic of foundation reuse were held at the Transportation Research Board's annual meetings in 2014 and 2015. More related sessions are planned for the TRB 2016 meeting.

"Given the high inventory of deficient bridges and budget deficit, reusing existing bridge foundations would save considerable costs and shorten delivery times significantly," says Mohammed Mulla, geotechnical engineer with the North Carolina Department of Transportation and chair of the TRB Soil and Rock Properties Committee, a key sponsor of the TRB sessions on foundation reuse.

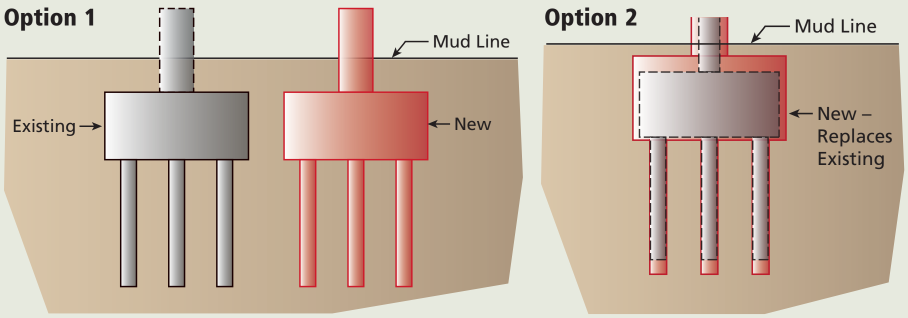
Reuse applications include replacement of the superstructure of an existing bridge because of structural deterioration, widening of an existing bridge, repurposing and reuse with strengthened foundations, and accelerated bridge construction (ABC) technologies, including prefabricated bridge elements and systems (PBES).

"The reuse of bridge foundations and substructures is also an important consideration for the ABC/PBES community," says Ben Beerman, senior structural engineer with the FHWA Resource Center. "When compared to other alternatives, it can be an effective strategy to meet the objectives of accelerated construction in the areas of time savings, cost reductions, improved safety, and the need to minimize site impacts."

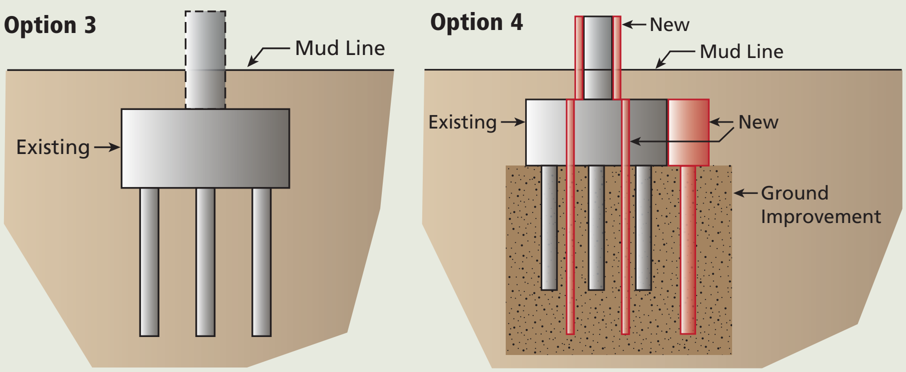
Beerman continues, "A unique and important outcome of this effort is to develop an AASHTO LRFD [American Association of State Highway and Transportation Officials Load and Resistance Factor Design] approach for foundation reuse. This is a paradigm shift [from] our current and past practices that will help advance our industry in a more unified and systematic manner."

The drivers for foundation reuse include asset management; reduced cost and time savings; efficiency; past performance (does not show any sign of excessive deterioration or movement); improved highway safety; reduced site, traffic, and environmental impacts; sustainability issues; and historic preservation. However, many challenges exist in the reuse of foundations. The primary concerns are the ability to accurately assess the integrity and capacity (structural and

Four Options for Bridge Foundations : Deep Foundation Example



When bridge engineers choose to replace or reuse a bridge foundation, they have four options. The first option for replacement is to build a new foundation adjacent to the existing one (option 1). The other replacement option is to demolish and remove the existing foundation and replace it with a new one (option 2).



Bridge engineers might choose to reuse a bridge foundation instead of replacing it. In that case, they can completely reuse the foundation (option 3), or they can reuse the existing foundation by strengthening and enhancing its capacity (option 4).

geotechnical) of existing foundations and the effects of their reuse when using current design codes. Determining the feasibility of foundation reuse requires multidisciplinary collaboration among staff with structural, hydraulic, geotechnical, and construction expertise.

Foundation Options

Four options exist for new developments on existing bridge sites.

Build a new foundation adjacent to an existing one. This option is perhaps the simplest from an engineering perspective. However, this option can be costly and may have the largest impact on the site from the environmental and permitting perspectives. If a new alignment is required, it may entail impacts related to property and right-of-way acquisition, in addition to utility accommodations. In river crossings, additional scour analysis is required to account for flow interference of the existing bridge piers with the proposed new piers during and after construction. (See "Hydraulics Testing of [Woodrow] Wilson Bridge Designs" in the March/April 2000 issue of PUBLIC ROADS.)

If the existing piers need to be removed, doing so requires additional time onsite. Often, pier foundations must be removed at or below the mudline to address the needs of partner permitting agencies.

Build a new in-place foundation. With this option, the existing foundation is demolished and replaced with a new one. When the new structure must be in the same place as the existing structure, removal and replacement of the existing foundation could be costly.

Reuse the existing foundation. This option requires no new foundation/substructure repair or rehabilitation work. The existing foundation is reused "as is" after a detailed assessment and analysis of the existing foundation's load-carrying capacity and condition to meet the service life of the design.

Reuse the existing foundation and strengthen and enhance the capacity. Examples of foundation enhancement include widening the pier stem; extending the pile cap and adding piles or shafts; soil improvement measures such as jet, compaction, or chemical grouting; and foundation underpinning using micropiles. The enhancement of the existing foundation reduces the risk associated with simply reusing the foundation "as is."

Foundation Reuse In Virginia

In one example, the Virginia Department of Transportation (VDOT) made the decision to reuse existing foundations for 10 bridges along the highly trafficked I–95 corridor near Richmond. The 4-year project began in September 2010. VDOT completed the project more than 3 months ahead of schedule and at a savings of nearly $16 million compared to fully replacing the bridges.

How did they do it? First, VDOT reduced the weight of the bridges by about 7 percent with the use of lightweight concrete for the new deck superstructures. The department analyzed the original foundations with this weight reduction and the proposed loading, and determined that the existing foundations were adequate to support the new superstructures with their reduced loads. Reusing the existing foundations saved the department considerable time and money.

When deciding whether to reuse the foundations, VDOT also evaluated the cost and remaining service life of reusing the repaired substructures with additional corrosion-protection countermeasures compared to the cost of entirely new substructures. The department found reuse to be the most cost-effective strategy.

In addition, VDOT did not want to disrupt traffic for the length of time that would have been required to replace the foundations. Because the existing foundations were adequate for the proposed loads, the department made the decision to reuse them after performing repairs and adding corrosion protection. The decision meant less disruption to traffic on the interstate. (For more on these projects, see "Keeping Virginia Moving" in the July/August 2015 issue of PUBLIC ROADS.)

The new steel truss superstructure of the Milton-Madison Bridge is shown here atop the permanent refurbished piers. The temporary piers are still visible to the right of the permanent piers.

Milton-Madison Bridge Project

Strengthening The Foundation: The Milton-Madison Bridge

When the aging Milton-Madison Bridge needed to be replaced, the Indiana Department of Transportation and the Kentucky Transportation Cabinet chose to reuse the existing foundations, while strengthening and enhancing their capacity. The agencies also employed innovative ABC/PBES techniques for the project, which broke ground in 2010, enabling them to shorten the delivery time considerably.

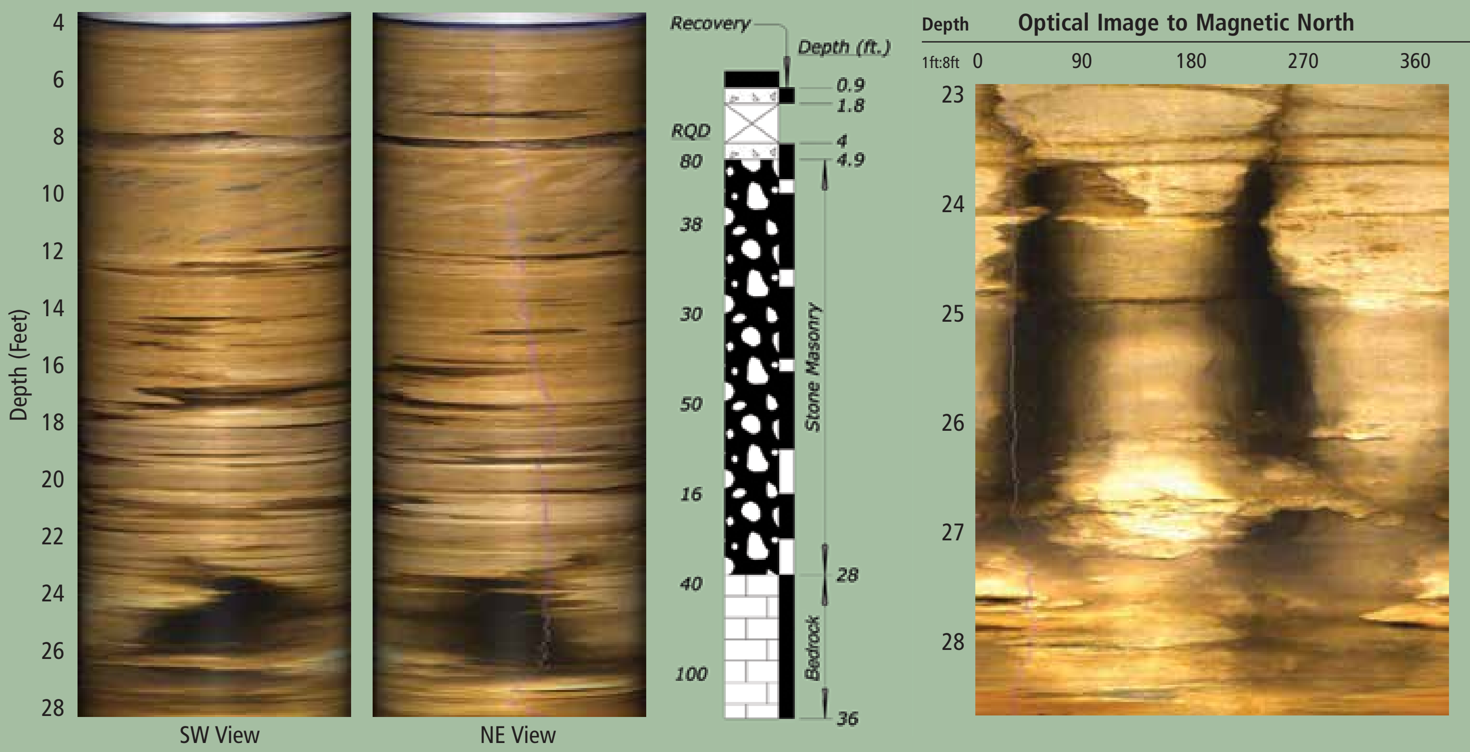
The Milton-Madison Bridge spans the Ohio River between Milton, KY, and Madison, IN. The project involved reusing and strengthening four of the five main piers, widening the pier stem, and replacing the superstructure using PBES. Project engineers evaluated soil-structure interaction for the existing foundations, which they ultimately strengthened by coring and adding supplemental reinforcement to the existing pneumatic caisson foundations (foundations built underwater). Considering the new design of the widened pier stem, hydraulics engineers performed extensive scour analysis, including design of scour countermeasures. The construction team then moved a preassembled steel truss superstructure from adjacent temporary piers 55 feet (17 meters) laterally onto the refurbished piers. This project is one of the world's largest river crossings to use the lateral slide method on existing foundations. The resulting effect on the traveling public was reduced from years to just a few days.

"Foundation reuse is one of the tools that needs to be in the owners' project development toolbox," says Aaron Stover, project manager with Michael Baker International. "In the case of the Milton-Madison Bridge, reuse and rehabilitation of the substructure on the existing alignment reduced environmental impacts and avoided right-of-way procurement and utility relocations. This innovative approach saved an estimated $50 million . . . compared to other new build alternatives and significantly reduced the overall project delivery timeline compared to typical projects."

Studying Foundation Reuse

In 2015, as part of the research agenda for the Foundation Characterization Research Program, FHWA selected the Willow Valley Bridge as the first field site for its assessment of technologies for foundation characterization and reuse. The bridge is located 40 miles (64 kilometers) southeast of Flagstaff, AZ, on I–17 along the low-volume Lake Mary Road. The rehabilitation plan proposed by FHWA's Central Federal Lands Highway Division (CFLHD) is to replace and widen the existing bridge superstructure.

FHWA studied the Willow Valley Bridge in Arizona as part of its research for the Foundation Characterization Research Program. Here, a section of the existing bridge is shown with its superstructure of concrete deck on pin-and-hanger steel girders. The superstructure is supported by a mass-gravity stone masonry wall foundation.



Shown here is an optical televiewer image of abutment 1, core hole B-5, of the Willow Valley Bridge in Arizona. The tool generates a continuous 360-degree image of the borehole wall. On the left are southwest and northeast views of compressed 3–D images of the core. In the center is a coring log, showing a cross section view of the core, with bedrock at the bottom, the stone masonry above that, and the bridge deck at the top. On the right is a flattened closeup of the televiewer image between the depths of 23 and 28 feet (7 and 8.5 meters), indicating open voids (the darkened areas).
Source: Colog, Inc.

The existing three-span bridge is 104 feet (32 meters) long and 34 feet (10 meters) wide. Construction of the bridge occurred in two phases: the original southern portion in 1934 and a widened northern portion in 1968. The bridge widening added three more girder lines. A mass-gravity substructure supports the pin-and-hanger steel girders and concrete deck superstructure. Each stone masonry wall foundation is built on rock, and the wingwalls at each abutment are masonry construction.

To reuse the foundations and ensure a safe and stable structural design, FHWA researchers thoroughly evaluated the existing foundations. Their evaluation included reviewing available information such as as-built drawings, conducting field evaluations, and drilling exploratory borings. The purpose was to demonstrate that the structural and geotechnical capacities and resistance of the foundation elements are sufficient to support design loads specified under the current AASHTO LRFD requirements.

For the exploratory borings, CFLHD staff decided to drill two 3-inch (8-centimeter)-diameter core holes at each foundation wall (abutments and piers). The core holes were drilled from the bridge deck through the mass-gravity columns into the underlying bedrock.

FHWA plans to publish a report in 2016 with the extensive data gathered for this study, but a sample of field results is presented below to highlight the capability of the technologies.

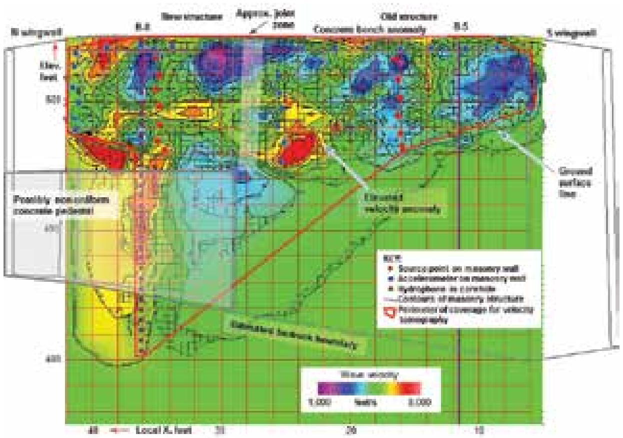
Geophysical Logging And Imaging

One useful technology for assessing foundations for reuse is wireline logging from the core holes. In concrete and masonry structures, wireline logging technology can assist in mapping cracks, present shear/Young's modulus as a function of depth, evaluate steel corrosion in reinforced concrete structures, and provide insights on the durability of the construction materials. The FHWA researchers applied wireline logging and imaging in their study of the Willow Valley Bridge.

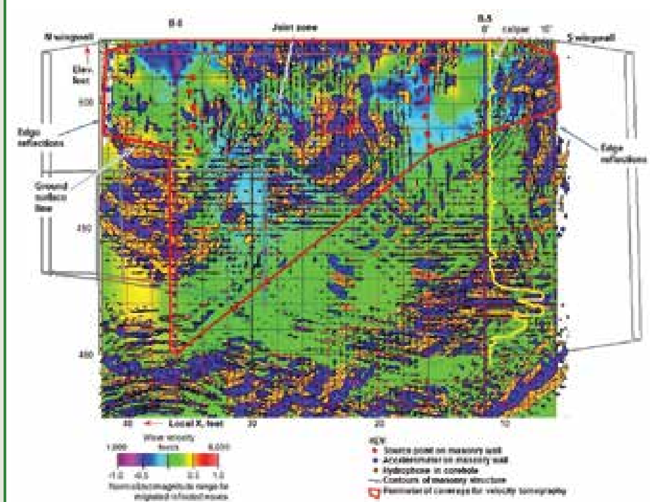
They used an optical televiewer tool, which generates a continuous 360-degree image of the core hole wall using an optical imaging system. The tool has sensors that correct for its orientation and create a photograph-like "virtual core" image of the core hole wall.

While wireline logging can provide detailed information on deteriotation of the foundation material around a core hole, other geophysical imaging technologies can produce three-dimensional (3–D) volumetric images for assessing structural integrity. A velocity tomogram, for example, indicates the distribution of acoustic velocity in the wall. Low velocities indicate possible anomalies.

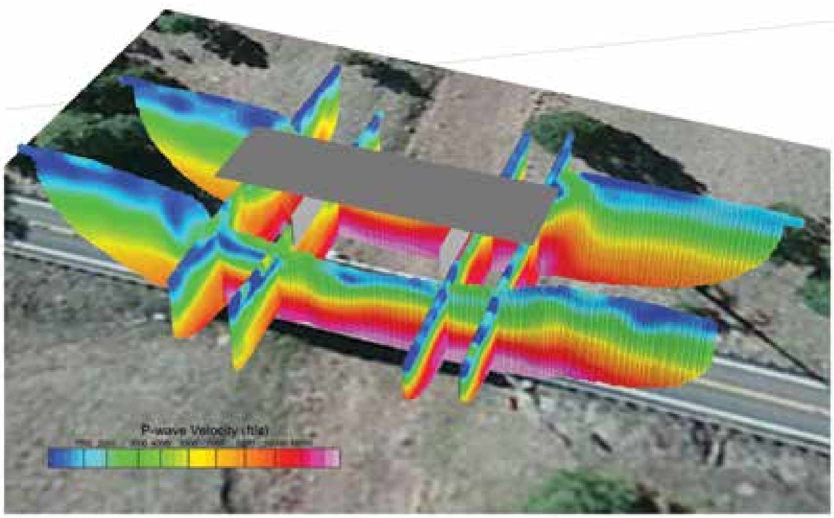
The researchers then used the velocity tomogram to obtain an image of the reflected (echoed) wave arrivals. The wave echoes create an image of the foundation wall and the voided areas. In the case of the Willow Valley Bridge, the imaged waveforms correlated well,



This tomogram of the Willow Valley Bridge shows a reconstructed velocity image in the stone masonry wall of abutment 1. The abutment (including the wingwall area) is shown in gray outline. The red line marks the perimeter of the area covered by the seismic survey. Low-velocity anomalies (blue color), indicating voids in the concrete, are visible along a 5-foot (1.5-meter)-deep zone toward the top of the abutment wall. *Source: C-Thru Ground.*



This reflectogram of abutment 1 of the Willow Valley Bridge is superimposed on the velocity model. It shows voided areas (shown in dark blue) both inside and outside the perimeter of the tomogram survey area (indicated by the red line). *Source: C-Thru Ground.*



This 3–D seismic refraction tomogram indicates that the bedrock under the Willow Valley Bridge is in good condition (based on distribution of the velocity field), with a slight dip. The 3–D velocity plot is displayed in a fence diagram superimposed on a Google Earth view of the bridge site. The location of the bridge deck is indicated by a dark rectangular shape in the center. *Source: Olson Engineering.*

not only with the known abutment wall boundaries, but also with the interpreted location of voids.

In addition, the researchers conducted several 3–D seismic and resistivity surveys to assess the condition and structures of the bedrock from the ground level. Each 3–D survey consisted of four lines placed parallel and close to each foundation wall and two lines in an orthogonal direction.

"The results obtained by this study assisted the FHWA Central Federal Lands office in developing a plan to grout the voids that were inherent in the original foundation walls [for the Willow Valley Bridge]," says Khamis Haramy, senior geotechnical engineer with FHWA's CFLHD. "It was also valuable in assessing the structural integrity and capacity of the foundation walls."

The Foundation Characterization Research Program is also developing a methodology for load testing of existing bridge foundations, including instrumentation for monitoring foundation response.

The degree and complexity of the surveys obtained by FHWA's Foundation Characterization Research Program might not be necessary for every foundation reuse project. However, the research program intends to deploy the technology at a reasonable cost and develop technical guidance and best practices for foundation reuse.

Frank Jalinoos is a research engineer at FHWA's Turner-Fairbank Highway Research Center. Jalinoos has nearly 30 years of experience with inservice bridge inspections, structural monitoring, sensor development, and ground imaging. He holds a master's degree in geophysical engineering from the Colorado School of Mines.

For more information, visit www.fhwa.dot.gov/research/tfhrc/programs/infrastructure/structures/fcp, or contact Frank Jalinoos at 202-493-3082 or frank.jalinoos@dot.gov.

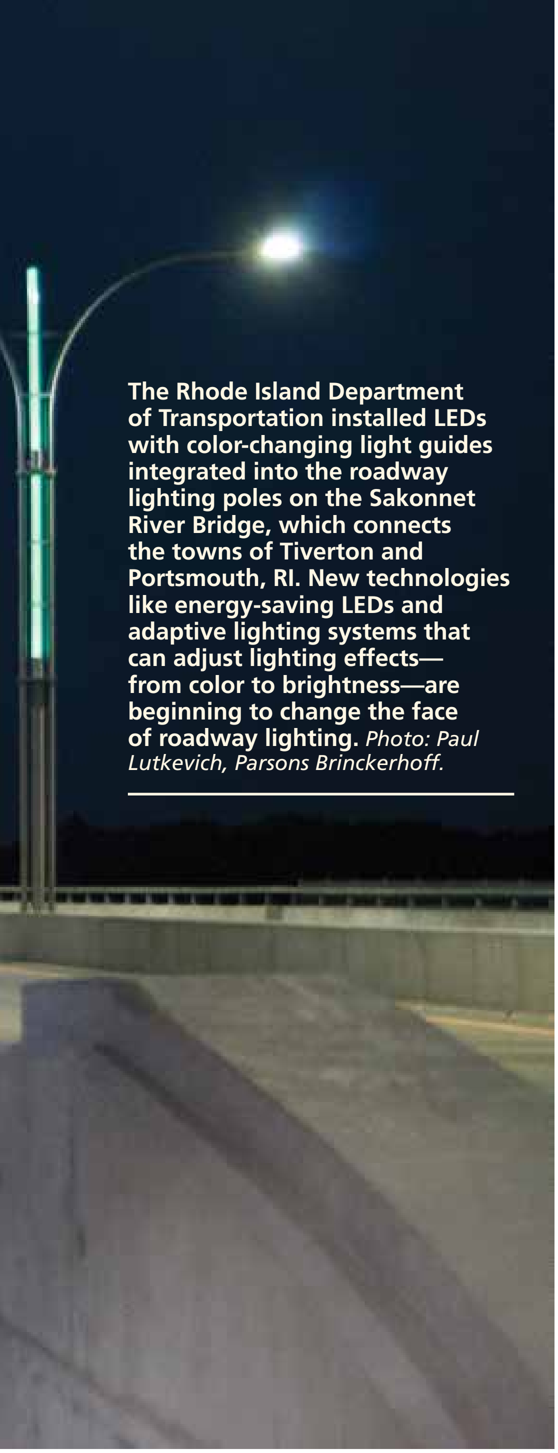
The Future of Roadway Lighting

by Ronald Gibbons, Joseph Cheung, and Paul Lutkevich

Researchers studying the role of illumination in traffic safety make the case for adaptive control systems.

Roadway lighting offers significant safety benefits but also represents a substantial share of the operating budgets of agencies tasked with maintaining the lighting infrastructure. Standard practice requires that roadway lighting systems, when installed, provide illumination for the maximum vehicle and pedestrian volume, regardless of roadway conditions or real-time roadway usage. Typical practice also requires maintaining a single, specific lighting level over time, which is difficult to do, because as a light source is used, it diminishes in output due to aging of the source and dirt that accumulates on the lens. To overcome the expected reduction in output, engineers tend to overcompensate in the initial lighting design by specifying the use of more intense luminaires to reach the correct lighting level.

These traditional approaches to lighting design result in significant over-lighting of roadways and excessive energy usage. Adaptive lighting, that is, adjusting illumination levels based on the needs of roadway users, offers an approach to overcome these challenges.



The Rhode Island Department of Transportation installed LEDs with color-changing light guides integrated into the roadway lighting poles on the Sakonnet River Bridge, which connects the towns of Tiverton and Portsmouth, RI. New technologies like energy-saving LEDs and adaptive lighting systems that can adjust lighting effects—from color to brightness—are beginning to change the face of roadway lighting. *Photo: Paul Lutkevich, Parsons Brinckerhoff.*

Driven by the development of new lighting technologies and a nationwide push to reduce energy use and environmental impacts, adaptive lighting is a growing trend in the roadway industry. It entails the use of a design methodology in which the light output of a system adjusts as traffic conditions change. More specifically, the level of lighting can be reduced or dimmed when traffic on highways or sidewalks lessens. Here's a look at how adaptive lighting may be implemented while maintaining the safety of road users and how two agencies are deploying this technology on their roadways.

Implementing Adaptive Lighting

Although transportation agencies have begun to introduce adaptive lighting into their roadway projects, the techniques for doing so have yet to be standardized. In 2011, the Federal Highway Administration's Office of Safety Research and Development launched the Strategic Initiative for the Evaluation of Reduced Lighting on Roadways to investigate the issues associated with the application of adaptive lighting to the roadway environment and to develop recommended practices for implementing those systems.

In July 2014, the FHWA Office of Safety Research and Development released a report titled *Design Criteria for Adaptive Roadway Lighting* (FHWA-HRT-14-051). This report describes an indepth effort to assess the effect of adaptive lighting on the overall safety performance of roadways. Researchers working with FHWA conducted studies to determine optimal times, conditions, and suitable approaches for reducing lighting; appropriate lighting levels for various roads and features; energy savings and reductions in greenhouse gases resulting from reduced lighting; and potential legal issues.

The resulting design methodology provides a process that transportation agencies can use to determine whether adaptive lighting is appropriate for a given roadway. The researchers proposed a set of criteria to assist jurisdictions in making sound, safety-based decisions when considering adaptive lighting approaches. In addition, the study's evaluation of real-world lighting data can serve as the foundation for future analyses related to roadway lighting.

Roadway Light, Visibility, and Safety

For part of the research resulting in the 2014 report, the FHWA Office of Safety Research and Development partnered with the Virginia Tech Transportation Institute to investigate how lighting levels affect safety on the road, and to develop an approach for selecting appropriate lighting levels for various roads and features. Previous research had shown that roadway lighting can affect crash risk. For this study, the researchers analyzed the relationship between lighting levels and quality and crash rates. Establishing such a relationship can help agencies determine the optimal lighting level for roadways under various traffic conditions.

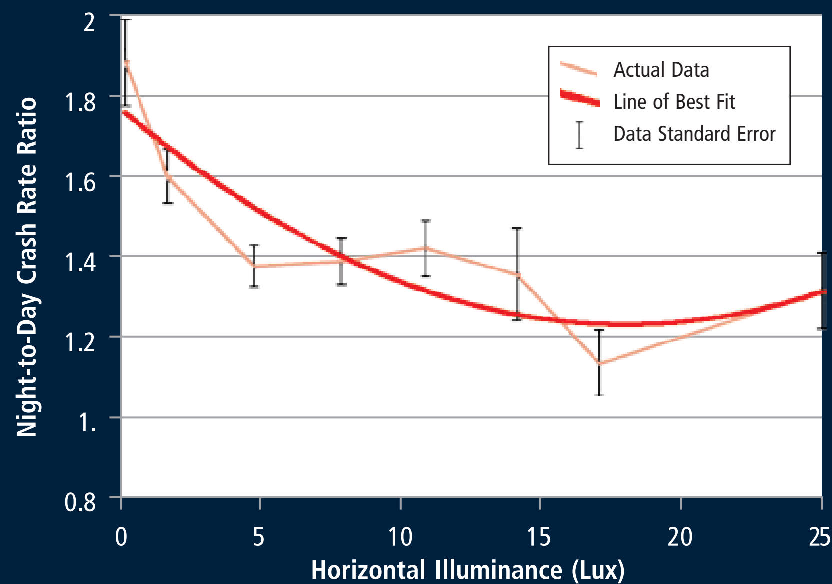
Four criteria to consider in the design of roadway lighting are horizontal and vertical illuminance, luminance, and uniformity. Horizontal roadway illuminance is the amount of light falling on the roadway surface. Vertical illuminance is the amount of light falling on a vertical surface, such as a pedestrian. Luminance is the amount of light perceived by the road user, and uniformity is the ratio of illuminance or luminance values, such as maximum to average, average to minimum, or maximum to minimum.

Researchers used detectors mounted on top of a vehicle to collect data to measure each of these criteria on thousands of miles of roadway in seven States (California, Delaware, Minnesota, North Carolina, Vermont, Virginia, and Washington). After taking measurements, the researchers compared the varying lighting levels, roadway characteristics, and traffic volumes with night-to-day crash rate ratios on segments of road. This ratio reflects the relative magnitude of nighttime crash risk compared with daytime crash risk.

Because daytime and nighttime crashes shared the same road design features and traffic control features, the crash rate ratio directly reflects the factors that only differ by day and night, with visibility level being the primary one. Therefore, the night-to-day crash rate ratio indicates the effect of lighting and light levels while controlling for the effects of roadway design, traffic control features, and other roadway characteristics. The researchers considered the night-to-day crash rate ratio to be the primary metric in evaluating the effect of roadway lighting on safety. (Note that weather conditions were not included in this analysis and therefore represent a basis for future research.)

The researchers analyzed more than 88,000 crashes that had occurred from 2004 to 2010. Of those, more than 64,000 crashes had occurred during the day, while nearly 24,000 had occurred at night. The National Oceanic and Atmospheric Administration's recorded sunrise and sunset times were used to

How Lighting Level Affects Safety on the Road



Note: 1 lux = 0.093 foot-candle.

Researchers calculated the relationship between the horizontal illuminance level and night-to-day crash rate ratio as part of a study to determine how the lighting level affects safety on the road. The results indicate that after you have added lighting (5 lux on the roadway), additional lighting does not necessarily always lead to a safer road, as evidenced by the minimal change in the crash rate as the road illuminance increased. *Source: FHWA.*

classify the natural lighting into daytime and nighttime conditions.

Horizontal Illuminance

Next, the researchers analyzed roadway horizontal illuminance, or the amount of light falling on the roadway surface, as one of four roadway lighting criteria in the study. They calculated the relationship between the horizontal illuminance of roadway segments and the night-to-day crash rate ratio of those segments.

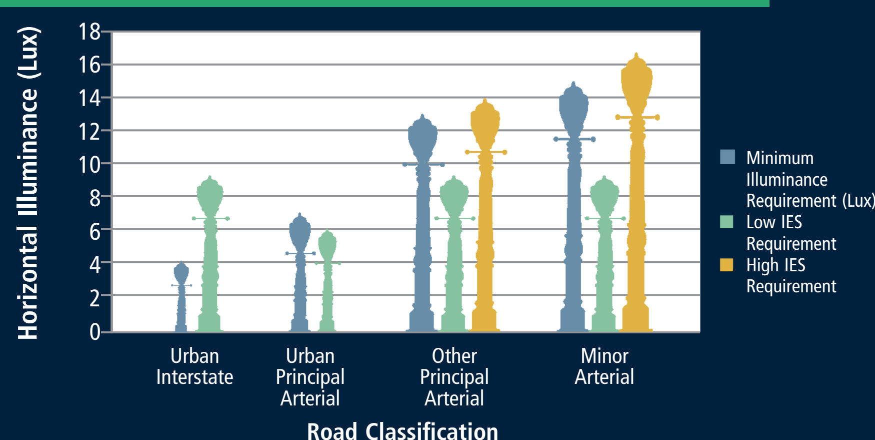
The results of their analysis show a significant decrease in the night-to-day crash rate ratio with an increase of average horizontal lighting levels, which are measured in foot-candles, or lux. In the study, the night-to-day crash rate ratios for lighting levels 0 and 0.1 foot-candle (0 and 1 lux) are significantly higher than for other levels. However, there is no statistically significant difference for lighting levels from 0.19 to 0.65 foot-candle (2 to 7 lux), and an increase in the lighting level from 0.46 foot-candle (5 lux) to higher levels did not appear to affect the crash rate ratio. There appears to be a further reduction in the crash rate at approximately 1.49 foot-candles (16 lux); however, because data on only 28 miles (45 kilometers) of roadway are represented in this category, the result is not statistically significant. These findings indicate that although lighting will benefit road safety, increasing the lighting level does not necessarily always lead to a safer road.

Maintaining Roadway Safety With Less Light

After conducting similar analyses for each of the other lighting metrics, the researchers concluded that the possibility exists for reducing standard lighting levels on roadways during periods of less traffic while maintaining the overall level of roadway safety.

In one case, the data revealed the potential for reducing standard lighting levels on urban interstates by as much as 50 percent. The researchers calculated the minimum illuminance requirement for various road classifications and compared those requirements with roadway lighting guidelines issued by the Illuminating Engineering Society of North America (IES). The research team calculated that the lighting level required for urban interstates is 0.37 foot-candle (4 lux), which is significantly less than the 0.84 foot-candle (9 lux) that IES recommends. The results for other roadway classifications show that the existing IES recommendations are suitable; the researchers'

Standard Lighting Levels for Various Road Types



Note: 1 lux = 0.093 foot-candle.

After calculating the minimum illuminance required for various road types, researchers compared the results to the guidelines issued by the Illuminating Engineering Society of North America. The data for urban interstates show that there is the potential to reduce standard lighting levels by as much as 50 percent. *Source: FHWA.*

Weighting Parameters for Roadways			
Parameter	**Options**	**Criteria**	**Weighting Value**
Speed	Very High	> 60 mi/h (97 km/h)	1
	High	45–60 mi/h (72–97 km/h)	0.5
	Moderate	< 45 mi/h (72 km/h)	0
Traffic Volume	High	> 30,000 average daily traffic	1
	Moderate	10,000–30,000 average daily traffic	0
	Low	< 10,000 average daily traffic	-1
Median	No		1
	Yes	Median must block glare	0
Intersection/Interchange Density	High	< 1.5 miles (2.4 km) between intersections	1
	Moderate	1.5–4 miles (2.4–6.4 km) between intersections	0
	Low	> 4 miles (6.4 km) between intersections	-1
Ambient Luminance	High	Moderately high ambient lighting or high ambient lighting	1
	Moderate	Moderate ambient lighting	0
	Low	Low ambient lighting	-1
Guidance	Good	> 0.03 foot-lambert (100 millicandela/meter squared lux)	0
	Poor	< 0.03 foot-lambert (100 millicandela/meter squared lux)	0.5

calculations resulted in lighting levels that fall within the range of IES minimum and maximum standards.

Selecting Lighting Levels

Selecting the appropriate lighting level for various roads and features is a critical aspect of adapting the lighting system. The International Commission on Illumination, a lighting standards organization, devised a system that provides both a methodology for selecting the lighting design level and a method for adapting the lighting level based on specified criteria for individual roadways. FHWA and the Virginia Tech Transportation Institute researchers based their design methodology on this system to comply with the international standard, but the team also proposes a more extensive classification system to take advantage of the benefits of adaptive lighting for roadways. Additional metrics include links to IES requirements and consideration of traffic volume, geometric design, and pedestrian volume.

The proposed system starts with the IES characterization of the facility to be lighted. The IES separates lighting design criteria by its application to roadways, streets, and residential or pedestrian facilities. First, roadway lighting criteria are provided for freeways, expressways, limited access roadways, and roads on which pedestrians, cyclists, and parked vehicles are generally not present. Second, street lighting criteria are provided for major, collector, and local roads where pedestrians and cyclists are generally present. Criteria for residential/pedestrian area lighting are provided primarily for the safety and security of pedestrians and not specifically for drivers. Once a lighting designer selects the facility type, he or she uses the characteristics of the facility as weighting functions to determine the requirements of the lighting system.

The designer then subtracts the sum of these weighting values from a base value. The base value changes based on the facility type. For roadways, the base value is 5. When the sum of the weighting values is subtracted from the base value, the result is called an "H-class." If the result of this calculation is not a whole number, the next lower positive whole number is used (for example, H3.5 would use the H3 lighting level class). Negative numbers would result in applying the highest lighting level, or H1 class. Similarly, if the calculated number is higher than the highest class number, the lowest lighting level, or H4 class, is used.

Once the lighting designer calculates the H-class, he or she determines the design criteria for the roadway. For each class, the lighting levels are specified in terms of average luminance, uniformity, and veiling luminance. The average luminance is the average lighting level on the roadway. The uniformity represents the ratio of the average to minimum light level and the average to maximum light level. These uniformity ratios control the range of light and dark on the roadway. The veiling luminance is a measure of glare and limits the amount of light that is projected by a luminaire towards a driver.

For an adaptive lighting system in which the lighting level changes based on the conditions of the roadway, the weighting functions

H-Class Lighting Design Levels for Roadways

Class	Average Luminance (cd/m²)*	Max Uniformity Ratio (average/ minimum)	Max Uniformity Ratio (maximum/ minimum)	Veiling Luminance Ratio
H1	1	3	5	0.3
H2	0.8	3.5	6	0.3
H3	0.6	3.5	6	0.3
H4	0.4	3.5	6	0.3

**Candela per square meter. 1 cd/m² = 0.29 foot-lambert.*

change as the roadway conditions change. This determines a different lighting class and therefore a different required design level.

Timing Lighting Adjustments

Some conditions that can change throughout the night and influence the lighting level required to maintain safety include traffic volume, pedestrian and bicycle presence, parked vehicles, ambient conditions, and pedestrian safety and security. As these conditions change, an adaptive lighting system will adjust luminance levels accordingly. (Weather conditions, such as fog, rain, and snow, are also factors that influence lighting level, but they were not included in this analysis.)

Two approaches typically used to trigger lighting adjustments in an adaptive system include curfews, in which the lighting system changes at a predetermined time, and roadway monitoring. Curfews are used to adapt lighting systems during defined time periods. Operators establish curfew times based on an evaluation of parameters of interest. For example, operators could evaluate average traffic and pedestrian volumes on an hourly basis to determine the timing of adaptive changes. Operators need to be able to override the adaptive cycle, as needed, for special events.

Actively monitoring the roadway through pedestrian and vehicle counts is an alternative to curfews. Active monitoring requires vehicle detectors or the review of roadway video to determine when to adjust lighting levels. The resource requirements for a monitoring system can be significant, although they might become less demanding once connected vehicle and connected infrastructure technologies provide a new source of data on traffic and pedestrian volumes.

Controlling Lighting Adjustments

The recommended technological approach to adaptive lighting is dimming. In the past, reduced lighting on roadways was typically accomplished through switching or "half-code" lighting, in which every other luminaire or the luminaires on one side of the roadway are turned off or removed. Although this method is cost effective, conserves energy, and is relatively easy to implement, half-code lighting makes it impossible to meet design criteria for uniformity and glare control. This approach presents legal issues because the inability to meet design criteria might affect the safety of roadway users.

In contrast, dimming a luminaire facilitates adjusting the light level without upsetting the other design criteria. Dimming luminaires are typically capable of dimming from 100-percent output to 10 percent of maximum output, depending on the technology of the light source. Although this method does not conserve as much energy as light-extinguishing methods, its ability to maintain lighting uniformity might be the best solution for conserving energy while minimizing the likelihood of negatively affecting driver or pedestrian safety.

Light-dimming methods have other advantages. Dimming lights instead of leaving them fully on at night reduces the effect of sky glow (a form of light pollution) and reduces disruptions to organisms' circadian rhythms—the physical, mental, and behavioral changes that follow a roughly 24-hour cycle, responding primarily to light and darkness in the environment. Disruptions to circadian rhythms can impact sleeping patterns and general health and well-being.

Dimming works particularly well with solid-state lighting, which uses semiconductor LEDs as a source of illumination rather than electric arc lighting and, by its nature, dims more smoothly. In addition, solid-state lighting conserves energy, typically yielding a 50-percent reduction in energy use over traditional lighting. Using an adaptive lighting design with solid-state luminaires can further reduce energy usage. Converting to solid-state luminaires also might reduce maintenance costs because they last longer than traditional light sources.

Legal Implications of Adaptive Lighting

The parties most concerned with the legal implications of an adaptive lighting system are the owners of such systems and their designers. The owner will likely be the government agency responsible for drafting the regulations defining the system and for implementing it. The designers include the engineers and design professionals working for the owner or agency.

The legal concerns involved range from the agency's justification for implementing such a system to the legal liability of the owners and designers in the event of a personal injury lawsuit attributed to the adaptive lighting system.

For the agency implementing an adaptive lighting system, demonstrating the basis for the application of its expert discretion is crucial when defending its decision to implement the system. Supporting the decision with empirical data will strengthen the case for needing the system, as will adherence to industry-accepted guidelines in the system's design. A narrative explanation of the agency's reasons for the decision to implement the system—written or endorsed by the engineers with the particular expertise—will leave little doubt as to the basis for the new system. A well-supported agency decision will likely receive substantial deference from a reviewing court.

Adaptive Lighting Systems in Use Today

San José, CA, has implemented a widespread adaptive lighting system. Since 2008, the city of San José has gradually upgraded its 62,000 yellow sodium vapor streetlights to use LEDs and paired them with a remote monitoring and adaptive control system. This approach enables the city to boost the efficiency and life expectancy of its streetlights, obtain timely and accurate information on the performance of its lights, and modulate lighting levels to provide only the amount of light needed.

The control system for the streetlight network provides real-time reporting of energy usage and non-operating streetlights for improved response. Converting to LED lighting reduced streetlight energy costs by 40 percent to 60 percent, while improving lighting quality and visibility and enhancing safety. The city is earning ongoing savings by extending the maintenance cycle for bulb replacement, and it receives credit from Pacific Gas and Electric (PG&E) for dimming its streetlights in the late evening hours.

"In 2011, San Jose supported the California Street Light Association in negotiations with PG&E for a pilot program to reduce the energy bill for controllable luminaires for a few streetlight customers," says Gregory Jobe, an associate engineer who works for the city. "By late 2015, we will have implemented a network-controlled dimmable streetlight pilot program open to all PG&E's streetlight customers at a reduced administrative cost. After an introductory period of a few months, the dimming schedule may be adjusted on an annual basis, and the tariff may be evaluated for potential modifications."

By switching to more energy-efficient lights and modulating its lighting levels in relation to changing activity levels, San José will save 1,885,000 kilowatt-hours annually, avoiding emissions equivalent to approximately 1,433 tons (1,300 metric tonnes) of carbon dioxide. That savings is equivalent to the volume of greenhouse gases emitted annually by 274 passenger vehicles.

San José aims to replace 100 percent of the city's streetlights with LED lighting equipped with an adaptive control system by 2022. The city expects to convert more than 20,000 lights by the end of 2015. So far, the city has concentrated on heavily used major roadways and a contiguous area in the southeastern portion of San José, including lights on a number of corridors identified as having a high percentage of pedestrian and bicyclist injuries and fatalities. Other priority locations include 20 areas identified by the local police department as gang activity hot spots, as well as areas with a high rate of streetlight wire theft. The streetlight control system provides real-time notification of circuit malfunctions, enabling the city to intervene and deter wire theft.

"Overall, residents have reported that they feel safer after dark because they can see better," says Amy Olay, planning and sustainability division manager with San José. "Others are impressed by the LEDs' lighting quality, although we have received some complaints. One complaint is that the lights are too bright, shining into houses. In those cases, we adjusted the tilt of the LED fixture to correct the problem."

Adaptive Lighting In Cambridge, MA

The city of Cambridge, MA, is replacing about 7,000 lights (4,900 streetlights and 2,100 in specialty and park fixtures) with LEDs and installing an adaptive control system that enables fine-tuning of light output, reduction of energy use, and energy usage tracking capabilities.

The city developed a system of classification to determine appropriate lighting levels for each street. Using detailed information from the city's geographic information systems database, as well as onsite evaluations, staff assessed streets for width, light pole spacing, and vehicular and pedestrian activity, and assigned each to categories corresponding to lighting criteria in accordance with industry guidelines, including the IES *Standard Practice for Roadway Lighting* (RP-8-14) and *Technical Memorandum on Light Trespass* (TM-11).

After comprehensive analysis, the city assigned the streets to a range of categories that address lighting requirements for both roadways and sidewalks, and limit glare and light trespass onto abutting properties. A wireless control system enables operators to dim the streetlights to 70 percent of their initial brightness. Later in the evening, the lights dim even further to about 35 percent of their initial brightness in response to low pedestrian volumes at that time of night. The new streetlight system consumes less than 25 percent of the energy of the existing streetlights, saving the city an estimated $500,000 per year in electricity costs.

"Cambridge's initial reasons for using adaptive controls were energy savings and asset management," says Glenn Heinmiller, a design consultant involved in the project. "But we soon realized that significantly reducing light trespass by dimming later in the evening was a huge benefit, especially in our dense residential neighborhoods."

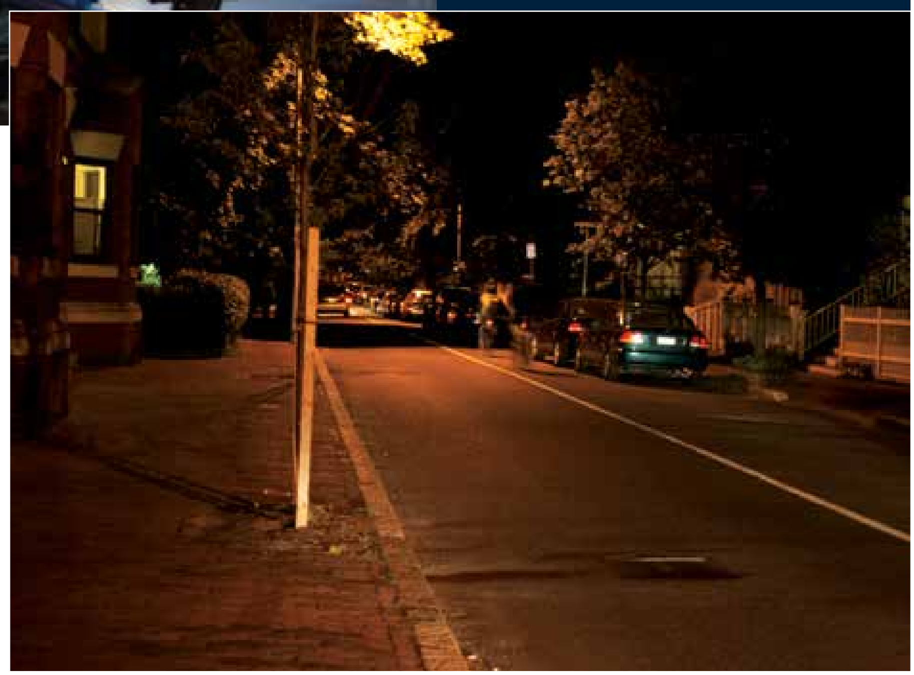
The new streetlights distribute light in a pattern similar to the old streetlights, but the amount of light crossing property lines from the public way will typically be half as much as with the existing lights, and even lower late at night. The new streetlights make colors look brighter and more faithful to the natural color. Trees look green instead of brown, a blue car looks blue instead of grey. Because of this improved color rendering, everything appears brighter and sharper under the new streetlights, even when the amount of light is less than with the old lights.

Lowered light levels are sometimes perceived as unsafe to roadway users and pedestrians, but residents in Cambridge have not raised concerns about the new lighting. "Based on our experience in Cambridge," Heinmiller says, "I think that fears that lowered light levels will be perceived as unsafe are unfounded. In our city of 100,000 residents, we've had no comments about lower levels. No one has complained or even seemed to notice when the light levels are cut in half."

The Future of Adaptive Lighting Systems

Adaptive lighting systems effectively reduce the cost and extent of the undesirable effects of roadway lighting while maintaining safety and usability. Integrating these systems with tools that are capable of sensing and communicating near real-time electrical and lighting data from the field will make

The city of Cambridge, MA, installed new LED fixtures operated by an adaptive control system along this residential street. The new luminaires (left) make colors look brighter and more faithful to the natural color, improving visibility even when the amount of light is less than with the old lights (below). *Photos: Paul Lutkevich, Parsons Brinckerhoff.*



it possible to control lighting levels more effectively—and even on demand. Vehicle-to-infrastructure communication systems that send real-time information to operating systems could control lighting in response to just a single vehicle.

The Virginia Tech Transportation Institute has created demonstration prototypes of an on-demand lighting system. On-demand lighting systems also could help first responders by flashing light where assistance is needed or along evacuation routes during disasters. Although these technologies are still in the early stages of development, adaptive systems are already shining light on today's increasingly dynamic roadway environment.

Ronald B. Gibbons, Ph.D., is director of the Center for Infrastructure-Based Safety Systems and is the lead lighting research scientist at the Virginia Tech Transportation Institute. He also is the director of Division 4 of the International Commission on Illumination and a past president of the IES. Gibbons earned his Ph.D. in systems design engineering from the University of Waterloo, Canada.

Joseph Cheung is a civil engineer in the FHWA Office of Safety, where he helps develop safety technologies. He has B.S. and M.S. degrees in civil engineering, with an emphasis on traffic and transportation, from the University of Maryland. Cheung is a registered professional engineer in Maryland.

Paul Lutkevich, P.E., has more than 30 years of experience in the design and research of exterior lighting systems. He is the past chair of the IES Roadway Lighting committee and Technical Review Council. He also is a member of the International Commission on Illumination. Lutkevich has a B.S. degree in electrical engineering from the University of Massachusetts Dartmouth.

For more information, see www.fhwa.dot.gov/publications/research/safety/14051/14051.pdf or contact Ron Gibbons at 540-231-1581 or rgibbons@vtti.vt.edu, Joe Cheung at 202-366-6994 or joseph.cheung@dot.gov, or Paul Lutkevich at 617-960-4903 or lutkevich@pbworld.com.

TRAFFIC INCIDENT MANAGEMENT SERIES: ARTICLE 6

Supporting Hometown Heroes

by Kimberly C. Vásconez

Successful traffic incident management programs depend on the participation of skilled multidisciplinary responders. Defining TIM as a new branch of public safety can help.

(Above) Relationship building among emergency response personnel, such as the fireman and policeman shown here attending to a crash, should occur prior to meeting at the site of an incident. Strong, well-established TIM programs help to foster these relationships. *Photo: © tillsonburg, iStockphoto.*

Building strong, sustainable traffic incident management (TIM) programs is essential for prompt and safe response on highways. But responders need support. They need backing from each other, from their senior leaders, and from the political infrastructure.

Most important, sustainable TIM programs cannot rest on the enthusiasm and good will of one or two champions. Those individuals play an important role in getting the TIM effort organized in a community. Over the past decade, however, the Federal Highway Administration and its TIM partners have found that unless a program is multidisciplinary and unless one of the governmental partners—usually the State or local department of transportation or law enforcement—assumes the lead, the TIM program will suffer serious setbacks when the champions retire or move on to other efforts.

Without a formal program, public safety professionals will, of course, continue to respond to traffic crashes and to apply TIM as an operational strategy, but usually without multidisciplinary planning or resource management. Instead, official TIM institutions typically evolve after a key partner faces losing its funding or support.

For example, the potential dissolution of the Florida Road Rangers, a safety service patrol program, in 2008 galvanized TIM partners within the State and across the country to find a way to explain convincingly that such DOT resources are not a courtesy, but critical and cost effective. Soon afterward, many courtesy patrols or freeway service patrols became "safety service patrols."

As understanding of the TIM discipline improves, many jurisdictions realize that institutionalizing these programs creates a more effective, efficient response. Large or small, programs provide an opportunity to build trust and relationships among multidisciplinary responders without the stress and risk encountered at the scene of an incident. Instead, TIM program partners meet regularly to assess issues and needs; develop legal agreements, if needed; create and update plans; and produce strategies to allocate fiscal, human, and equipment resources most effectively. When TIM programs are firmly established as essential services, the frequency of contact among the response partners increases and communications improve.

The Building Blocks Of a TIM Program

TIM programs begin at the grassroots level. Most often, they start with an agreement between a DOT and State or county police. Once these groups agree to formalize a TIM program, they consider which additional organizations to invite to the planning table. Although many jurisdictions include county fire and rescue officials on the TIM team, some programs have not.

"Stakeholders need to regard traffic incident management as a continuous, comprehensive program that includes all responder disciplines," says Dave Bergner, a principal with Monte Vista Associates, LLC, and retired public works superintendent and traffic operations manager in Overland Park, KS.

He continues, "The 'four Cs'—communication, collaboration, coordination, and cooperation—are the guiding precepts for the Incident Command System, the foundation of TIM. Each discipline must acknowledge that operating with common policies, protocols, and practices is essential to avoid confusion and conflict. For TIM to be successful in the long term, organizations must incorporate these concepts as part of their standard operating procedures. They should also view TIM as more than an 'as needed' function; it should be considered an ongoing activity that requires regular planning, preparation, and performance measurement."

Preparing responders to hit the ground running requires a great deal of effort. To address this need, FHWA deploys TIM responder training courses that include a 10-hour train-the-trainer option, a 4-hour classroom session, and a Web-based offering for individuals. These foundational courses help unify operations, terminology, and best practices among TIM responders across the country.

In addition, responders must be supported by an administrative and programmatic team that addresses the following: (1) ensures that fiscal and human resources are available; (2) conducts regular multidisciplinary meetings; (3) develops and updates TIM program implementation plans, including TIM sections in metropolitan transportation improvement plans and strategic highway safety plans; (4) prepares and updates agreements among partners, especially where roles and authorities must be spelled out (for example, mutual aid, bi-agency agreements); (5) collaborates on multidisciplinary training strategies and conducts joint training, drills, and exercises; (6) assesses the needs of the program and of the responders; (7) identifies ways to share activity costs for the TIM program; and (8) integrates contracting mechanisms to accommodate multidisciplinary budgets and ways to allocate funding.

Tools for a Successful TIM Program

Most TIM operations, particularly in larger metropolitan areas, include an administrative program. With more information now available on TIM programs and more than 100,000 practitioners now trained, many TIM program managers are working to improve their programs. Successful programs offer examples of how to accomplish this.

To determine what constitutes a successful program, FHWA developed a self-assessment tool that can help jurisdictions determine where they stand relative to TIM best practices. In 2003, when the voluntary self-assessments began, approximately 70 jurisdictions agreed to participate with the understanding that it would help them progressively improve their programs.

The summary reports are available on the Office of Operations Web site at www.ops.fhwa.dot.gov/eto_tim_pse/preparedness/tim/self.htm. The

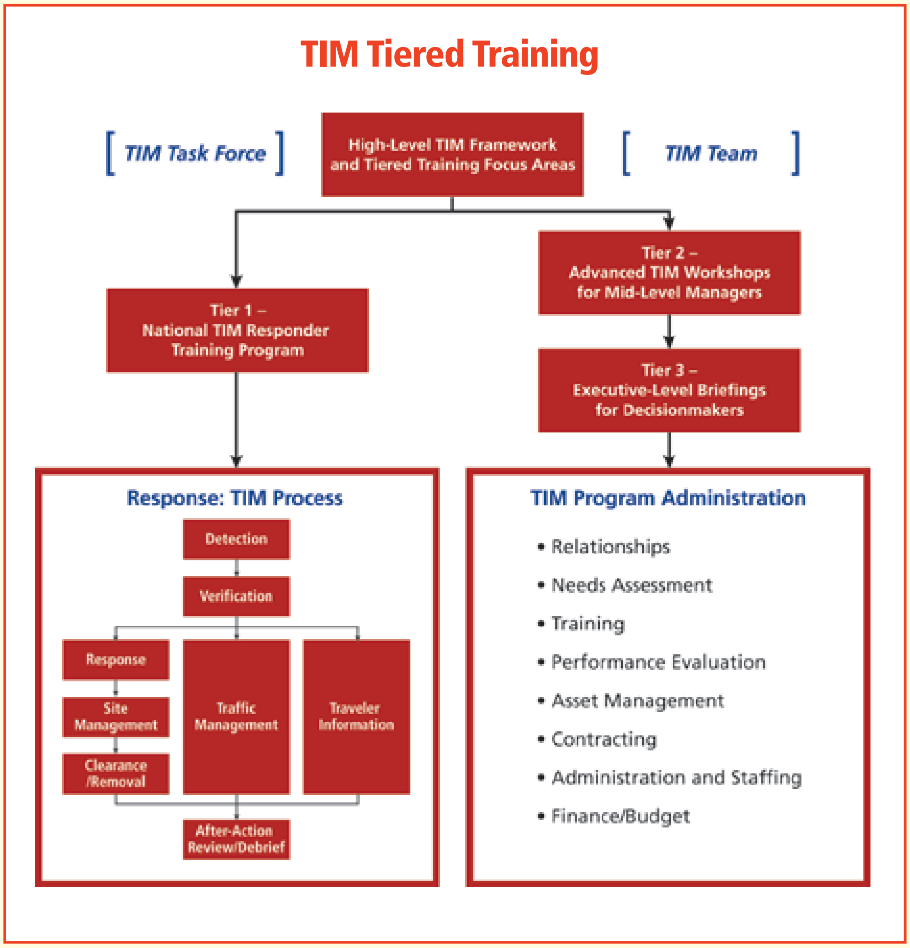
PUBLIC ROADS Series on Traffic Incident Management

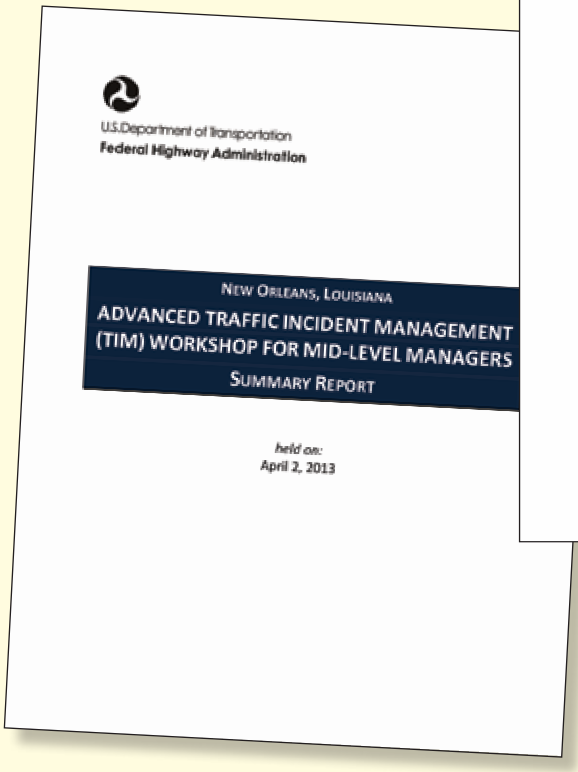
- July/August 2013, Guest Editorial, "Turning the National Spotlight on TIM," by Jeffrey Lindley, Associate Administrator, FHWA Office of Operations
- July/August 2013, Article 1, "Successfully Managing Traffic Incidents Is No Accident," by Kimberly C. Vásconez
- November/December 2013, Article 2, "Training Millions of Responders," by Kimberly C. Vásconez
- July/August 2014, Article 3, "Living in the Line of Duty," by Dennis L. Rubin and Kimberly C. Vásconez
- March/April 2015, Article 4, "Clearing Crashes on Arterials," by Dave Bergner and Kimberly C. Vásconez
- May/June 2015, Article 5, "A Pivotal Job for Police," by Jeffrey A. King
- November/December 2015, Guest Editorial, "TIM: An Important Operations Strategy," by Jeffrey Lindley, Associate Administrator, FHWA Office of Operations
- November/December 2015, Article 6, "Supporting Hometown Heroes," by Kimberly C. Vásconez

self-assessment tool proved to be so valuable that, in 2014, nearly 100 jurisdictions used it and submitted their results to the program office.

From 2010 to the present, FHWA has offered another tool to help jurisdictions develop action plans specific to improving their TIM programs. FHWA facilitated this self-analysis and planning effort through delivery of advanced TIM workshops for mid-level managers. Workshop participants reviewed the TIM National Unified Goal's strategies and determined where they needed help. For more information on the National Unified Goal, see http://ntimc.transportation.org/Documents/NUGUnifiedGoal-Nov07.pdf.

FHWA conducted the workshops in the 40 largest metropolitan areas from 2010 to 2012, and since then the agency has responded to requests from about 4 additional jurisdictions each year. Local organizers, usually State DOTs and police, also gathered regional decisionmakers to discuss the importance of the TIM program as both safety and congestion strategies. Finally, FHWA, in conjunction with the Transportation Research Board and the American Association of State Highway and Transportation Officials, developed a Capability Maturity Framework that will help identify programmatic strengths and areas for improvement.

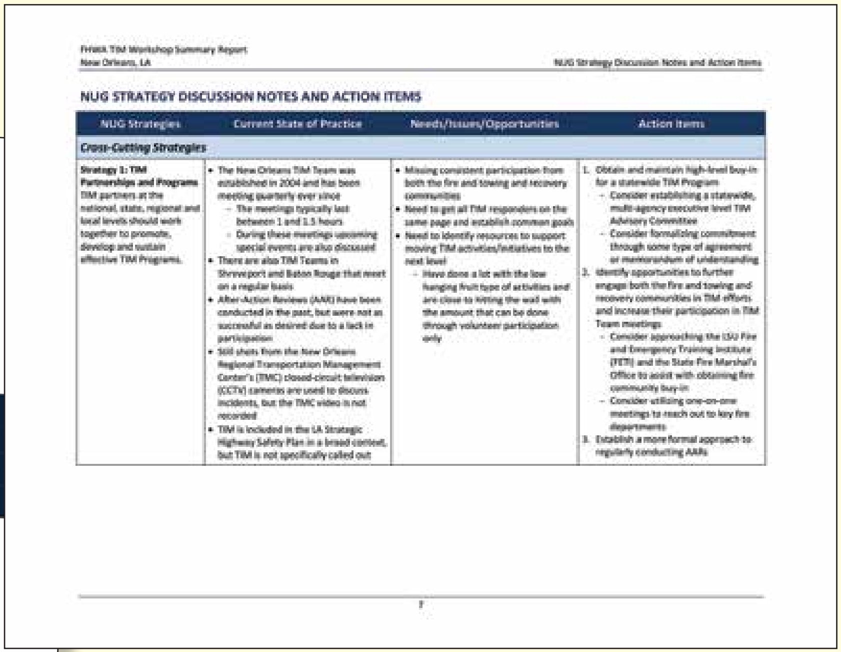




U.S. Department of Transportation
Federal Highway Administration

New Orleans, Louisiana
Advanced Traffic Incident Management (TIM) Workshop for Mid-Level Managers
Summary Report

held on:
April 2, 2013



FHWA TIM Workshop Summary Report
New Orleans, LA

NUG Strategy Discussion Notes and Action Items

NUG STRATEGY DISCUSSION NOTES AND ACTION ITEMS

NUG Strategies	Current State of Practice	Needs/Issues/Opportunities	Action Items
Cross-Cutting Strategies			
Strategy 1: TIM Partnerships and Programs TIM partners at the national, state, regional and local levels should work together to promote, develop and sustain effective TIM Programs.	• The New Orleans TIM Team was established in 2004 and has been meeting quarterly ever since – The meetings typically last between 1 and 1.5 hours – During these meetings upcoming special events are also discussed • There are also TIM Teams in Shreveport and Baton Rouge that meet on a regular basis • After-Action Reviews (AAR) have been conducted in the past, but were not as successful as desired due to a lack in participation • Still shots from the New Orleans Regional Transportation Management Center's (TMC) closed-circuit television (CCTV) cameras are used to discuss incidents, but the TMC video is not recorded • TIM is included in the LA Strategic Highway Safety Plan in a broad context, but TIM is not specifically called out	• Missing consistent participation from both the fire and towing and recovery communities • Need to get all TIM responders on the same page and establish common goals • Need to identify resources to support moving TIM activities/initiatives to the next level – Have done a lot with the low hanging fruit type of activities and are close to hitting the wall with the amount that can be done through volunteer participation only	1. Obtain and maintain high-level buy-in for a statewide TIM Program – Consider establishing a statewide, multi-agency executive level TIM Advisory Committee – Consider formalizing commitment through some type of agreement or memorandum of understanding 2. Identify opportunities to further engage both the fire and towing and recovery communities in TIM efforts and increase their participation in TIM Team meetings – Consider approaching the LSU Fire and Emergency Training Institute (FETI) and the State Fire Marshal's Office to assist with obtaining fire community buy-in – Consider utilizing one-on-one meetings to reach out to key fire departments 3. Establish a more formal approach to regularly conducting AARs

7

More than 50 of the most populous metro areas developed a TIM action plan, such as this one from New Orleans, LA, as a part of the FHWA advanced TIM workshops held from 2010 through 2012. The plans provide a framework for institutionalizing TIM programs in those metro areas.

Examples of Strong TIM Agreements

Several programs offer effective models for traffic incident management, including the Wisconsin Traffic Incident Management Enhancement (TIME) Coalition Partnering Agreement, the Maryland Coordinated Highways Action Response Team (CHART), and the Georgia Highway Emergency Response Operators (HERO) program. Below are a couple others:

The Washington State DOT, State Patrol, and Fire Chiefs' Joint Operations Policy Statement covers data sharing, winter operations, coordinated public communication, work zone safety, and TIM. The TIM subsections include a 90-minute clearance goal; responder safety; safe, quick clearance; an incidence response team program; contracted service patrols and motorist assistance vans; an instant tow dispatch program; a major incident tow program; and use of technology and education to expedite investigations. For more information, see http://wsdot.wa.gov/Operations/IncidentResponse.

The Indiana State TIM Effort (IN-TIME) formally committed signatories to a multilateral agreement centered on agencies adopting an "Open Roads" philosophy. It states, "All agency responders, after ensuring their own personal safety and the safety and security of any incident victims, should have as their top priority reducing congestion and the higher risks of secondary crashes for public/motorist safety." The agreement also requires that a representative from each signing agency actively participate on the IN-TIME team. The group sets a common framework for TIM policies and training programs across the responder discipline. IN-TIME members are given voting rights, and best practices are an example of something that would be voted on by the group.

Through research and discussions with hundreds of TIM professionals, FHWA identified the following six best practices and elements of effective programs.

TIM Staff, Partnering Agreements

First, one sign of a healthy program is the maintenance of a cadre of dedicated professional staff responsible for administering the TIM program as a primary job function, with liaisons in each partnering organization.

The staff members should have an understanding of the roles and responsibilities, and ensure that formal agreements are in place. These may be multiagency agreements or memoranda of understanding (MOUs) between two or more groups representing different disciplines, including law enforcement and the DOT, at a minimum. For the agreement or MOU to aid groups in institutionalizing TIM programs, the highest ranking official for each participating agency should sign it.

The agreement or MOU will define the TIM program objective and each participating agency's roles and responsibilities. It also will state the program's time goals for quick clearance of crashes.

Multiagency Membership

Second, a good program will have a multiagency TIM team that typically includes membership from law enforcement, transportation, fire and rescue, emergency medical services (EMS), towing and recovery, safety service patrols, and public works, if appropriate. Effective TIM teams meet regularly, often quarterly, and conduct incident debriefings on responses that reach specified thresholds (for example, those taking more than 90 minutes to clear).

The selection of TIM team members should consider the following: (1) agency responsibility for incident management response or administration; (2) agency area of responsibilities for TIM (for example, some representatives should come from the maintenance and traffic operations divisions of DOTs); (3) stakeholders affected by TIM operations; (4) stakeholders who might be able to help raise awareness of TIM; and (5) roles within other organizations, such as metropolitan planning organizations (MPOs), private sector EMS, traffic reporters, elected officials, debris clearance experts, and hazardous materials (hazmat) contractors.

Stakeholders—the public or traffic reporters, for example—might be among the most important to include because the TIM program is built around the unique needs and resources of an area. For example, the *Florida Traffic Incident Management Strategic Plan* recommends including a representative from a grassroots advocacy group to provide a perspective from the public concerned with motorist safety to the State TIM steering committee. Building a coalition of those who conduct TIM operations and key stakeholders will lead to a more effective program.

Although law enforcement usually leads roadway operations, DOTs often serve as the administrative lead for the TIM team. However, many successful TIM programs use an MPO to coordinate the program, especially the planning effort. When the TIM team covers multiple jurisdictions, the team might need to include representatives from more than one fire department, law enforcement agency, public and private EMS, and so forth.

Most successful TIM programs include the following representatives on the TIM team:

Law Enforcement. This discipline might include city, county, regional, or State police. Most frequently, this discipline receives the first call. Law enforcement also collects performance metrics, such as time taken to open a lane and whether the incident is secondary (that is, related to another incident downstream).

Fire and Rescue. Paid State, city, rural, and tribal, as well as volunteer, fire departments provide temporary traffic control and handle car fires and hazmat situations. Rescue workers extricate motorists using the Jaws of Life®.

Medical. This discipline includes the emergency medical team, the coroner's office, ambulances, and medevac capabilities.

Transportation and Public Works. These resources provide debris clearance; temporary infrastructure repairs; temporary traffic control, including lane blocking; safety service patrols to aid motorists with disabled vehicles in need of minor vehicle work (for example, adding gas or changing a tire);

FHWA's "Move It" public service announcement reminds motorists that if you have a minor incident and are not seriously injured, and if your car is drivable, then you should move it.

provision of documentation; and services to push vehicles off the road.

Safety Service Patrol/Freeway Service Patrol (SSP/FSP). Patrol programs throughout the United States are tasked with supporting safe, quick clearance. SSP/FSP stakeholders may include contracted towing companies, State DOTs, private SSP providers, and consultants.

Towing and Recovery. These personnel primarily remove disabled vehicles, clear incident debris, and clean up spilled cargo. Stakeholders include private towing companies, the Towing and Recovery Association of America, and Wreckmaster-certified operators.

Traffic Management Center. TMC staff members manage incidents, control traffic, and provide accurate information to the traveling public so that motorists can make informed choices in order to avoid incidents. TMCs collect incident data (reports, photos, and videos), confirm and analyze information, and communicate that information to incident responders and to the public. TMCs often serve as the nerve center where intelligent transportation system technology such as closed-circuit television cameras, dynamic message signs, and other tools are available.

A Training Plan

A third characteristic of effective programs is maintaining a multiagency training plan and calendar. Successful programs seek out opportunities for the TIM task force to train, drill, or conduct exercises at least once per year.

Innovative jurisdictions ask the TIM team to contribute to multifunctional plans for large special events, especially those with the designation of National Special Security Event. Although a TIM plan will not be incorporated in its entirety in the special plans developed for larger events, the TIM team might provide resources and operational input to a regional emergency transportation coordinator.

TIM teams also might staff operations centers—whether emergency operations centers or transportation operations centers—and conduct watches during an event. They might pre-position TIM task force elements and execute an after-action review to evaluate the multifunctional plan, just as TIM task forces evaluate their operation after a response.

"Emergency management agencies coordinate with the various departments and agencies with regard to planned special events," says Laurel Radow, FHWA's evacuations and planned special events program manager. "On the day of the event, these agencies often stand watch during the event and assess the plans based on the activities during the watch. Similarly, for the transportation-specific parts of planned special events, the appropriate transportation agencies bring together TIM planners to prepare for the special events' transportation plans, including transit and pedestrian plans. The TMCs serve as operations centers for planned special events in order to manage the event, as well as test TMC staffs' ability to support nonrecurring incidents."

Another characteristic of an effective TIM program is the identification of responders who are likely to deploy to traffic crashes or other incidents, plus the development of a TIM responder roster and call-down list. The roster and call-down list make deployment smoother when larger teams are needed. This way, the TIM program can develop task forces and target training toward those who need the skills to respond.

Performance Measures

Fourth, an effective TIM program develops a plan to collect, analyze, and process performance measurements. Usually, the TIM partners build into their multiagency agreements standards for roadway clearance (the time a lane is blocked), incident clearance (the time that responders are at the scene), and secondary crashes (the number of incidents caused by a primary event downstream) to measure the impact on motorists.

They might also account for line-of-duty deaths or responder injuries as performance measurements of responder safety. Partners in an effective TIM program need to analyze data at least quarterly to evaluate overall performance and develop strategies to improve responses. FHWA's new TIM Benefit-Cost tool is now available to aid in analyzing data.

Public Awareness

Fifth, the TIM team should partner with traffic reporters to make the public aware of their responsibility to comply with laws to move over and slow down.

FHWA, in conjunction with the Emergency Responder Safety Institute and a contractor, developed a "Move It" public service announcement, available at www.respondersafety.com/Videos/Move-It.aspx. The "Slow Down Move Over" PSA is available at www.respondersafety.com/Videos/Slow-Down-Move-Over.aspx. FHWA provides a variety of other materials for public communications in its TIM Outreach Toolkit

This highway incident involving an overturned vehicle was inaccurately called into a towing company as a minor fender bender. By taking a photograph of the scene using a mobile device and sending it to towing operators, personnel at the scene enable centers to use their own expertise to rapidly identify and deploy the type of equipment needed. *Photo: Jeff Roskopf, Roskopf's Service & Towing.*

for jurisdictions to use to make drivers aware of their duties and the law. The TIM Outreach Toolkit is available at http://ops.fhwa.dot.gov/eto_tim_pse/timtoolbox.

Safety Service Patrols And Towing

Lastly, an effective TIM program often will integrate a regional safety service patrol into its TIM planning and field training, exercises, and operations. SSPs are effective public relations tools for DOTs but can be underutilized and occasionally forgotten when planning for TIM.

A jurisdiction must determine what it can afford in terms of the hours of operation, routes/lane-miles covered, and the extent of the services offered. For example, will SSPs be trained in basic life support and major mechanical fixes? If the SSP is not on call 24/7, then a backup organization must be designated and be prepared to respond quickly. Often fire and rescue cover for SSPs in terms of lane blocking and temporary traffic control, or to address minor mechanical malfunctions.

Many TIM programs also find that establishing contracts in advance with towing companies accelerates the delivery of equipment when needed. Towing companies are the principal private sector resource integrated into the TIM task force. As such, those who arrive at the scene first—especially law enforcement, SSPs, and fire and rescue—should train their staff on how to request the proper towing equipment. In some areas, laws determine who may call for towing assistance.

The Towing and Recovery Association of America conducts training with law enforcement and has produced a visor card to help responders know how to describe the vehicle, incident, and impact. The towing company, if given the right information, will send the right equipment. Smartphones and instant dispatching of photos also help the towing company determine the correct resources to send.

Effective TIM programs offer towing agreements and contracts to make procurements quickly, and some even offer incentive programs to encourage faster cleanup and removal of vehicles and debris. The same type of prenegotiated contracts

An FHWA TIM expert from headquarters speaks to senior public safety managers at a workshop in San Juan, Puerto Rico, about their role in traffic incident management.

Steve Cyra, HNTB

with incentive programs might be established with hazmat companies.

Additional Best Practices

Effective TIM programs use the resources available from MPOs for planning and funding. And, the TIM teams develop implementation plans, as well as sections to be included in the mandatory metropolitan transportation improvement plans and State strategic highway safety plans.

Effective programs will also plan for the least frequent scenarios. TIM implementation plans should establish thresholds for reporting the types and the amount of hazmat, as well as procedures that allow jurisdictions to call their own contractors when the responsible party cannot conduct the cleanup quickly. Plans should also document when to call medical examiners to the scene and how to handle deceased victims prior to the arrival of the medical examiner.

The TIM partners must also meet routinely with elected leaders to ensure their commitment to and support of the program, which translate into resource security.

The TIM team works with tactical leaders from the TIM task forces to document policies and procedures for incident response and clearance. The tactical plans should address the latitude that authorities have to remove vehicles, especially if there is a law that permits authorities to move vehicles that are causing safety hazards. It should also document the jurisdiction's driver removal, or "move it," law and the parameters and circumstances in which drivers may move or drive their vehicles to safe locations. If State and local laws require motorists to remove their vehicles from the road when they are drivable, then their law enforcement responders should have the technology and ability to reconstruct the crash for investigations.

TIM programs have the responsibility to ensure that their responders utilize personal protective equipment, including high-visibility vests, for all operations. In addition, program disciplines must ensure that their responders understand and utilize the national Incident Command System, including the principles of scalable response and unified command. Also, those who conduct temporary traffic control must be familiar with the guidelines in the *Manual on Uniform Traffic Control Devices* and how to stage response vehicles to protect responders and those motorists involved in the crash.

Effective programs also define the role of TMCs in supporting operations, including dispatching resources and reporting to TIM team members on the status of the operation. The best TMC operations colocate law enforcement, fire and rescue, and traffic reporters for rapid coordination and to share information collected through dispatch systems (if not conducted from the TMC), video feeds, signal timing, opening/closing of ramps and ramp metering, and dynamic message boards for critical messages to the motoring public. The TMC also can furnish motorists with real-time traveler information via its Web site or 511 services, including travel time estimates and alternate routes for avoiding the area.

Organizing the Program

Currently, TIM programs across the country are in various states of development. As long as public safety agencies have plans and processes in place to deploy resources to help stranded motorists, there is a TIM program, regardless of whether it has a formal administrative multidisciplinary program. TIM organizations typically follow common steps; however, a cookie-cutter approach does not fit all scenarios. For example, laws may require that only law enforcement call for towing support, and the division of responsibilities can differ across the country. In addition, some SSPs might be owned and operated by public works departments rather than local DOTs. Or, hazmat resources might come from environmental protection organizations rather than local fire and rescue.

"As a best practice, it is important for agencies to ensure that TIM practices are institutionalized, which may include preparing standard operating procedures and analyzing performance data," says Joseph Sagal, TIM subject matter expert with the Operations Team in FHWA's Resource Center and former deputy director for operations at the Maryland State Highway Administration, overseeing the Maryland Coordinated Highways Action Response Team (CHART) program.

Steve Cyra, HNTB

This sign welcomed attendees to a TIM workshop for mid- to senior-level public safety managers in San Juan, Puerto Rico.

He continues, "Frequent and consistent meetings, such as regional MPO meetings held with agendas focusing on TIM efforts, are paramount at all levels, from senior executives and political leaders, down to the boots on the street responding day to day. These sustained efforts are just as important for ensuring a mature TIM program as responding to the actual incidents."

The *Strategic Plan for Highway Incident Management in Tennessee* provides a sample chronology of activities and milestones to evolve from localized TIM efforts to a statewide program. An abridged version of the chronology includes the following: (1) start a TIM program locally in one area of the State, (2) leverage intelligent transportation systems plans and programs for TIM, (3) utilize TIM service patrols to build support for the program, and (4) obtain the necessary legislation and authority for TIM responders.

Often TIM teams and administrative operations do not receive the same attention as the field responders. However, TIM teams play a critical role in institutionalizing TIM. The following benefits accrue to TIM programs through the administrative teams and actions:

- Program stakeholders demonstrate early success and leverage that success to expand the program to additional cities, counties, or regions.
- Stakeholders build relationships and lines of communications over time rather than overwhelming any one individual or group of individuals.
- Administrators evaluate the program early on and make course corrections based on lessons learned.

TIM program leaders overseeing an emerging program benefit from other programs that have developed robust model programs. This helps the newer programs avoid hard lessons and trial and error. FHWA's Office of Operations, the Operations Team in FHWA's Resource Center, and FHWA division offices can help match programs and support peer-to-peer exchanges and other technology transfer activities.

Once team membership has been determined, the TIM team leader should arrange a kickoff meeting if no formal planning structure currently exists. If the team is formally constituted after years of ad hoc operations, the group should meet to define their vision, mission, goals, objectives, and challenges.

Measuring Success

TIM partners need to work together to identify how disruptive traffic incidents are to a community in terms of congestion, safety to motorists and responders, livability, contribution to environmental damages, and the added costs of delayed freight. To do so, partners must collect the data needed for a holistic view of traffic incident impacts.

TIM programs should look at three common challenges that may be quantified and measured. These include the following: (1) the frequency of incidents by location, time of day, season and weather, and other special circumstances; (2) the duration of incident response; and (3) the traffic impacts of these incidents. By continually measuring these three metrics, programs can identify where to focus resources and improvements.

Data sources for incident frequency and duration may be obtained through law enforcement crash reports. In most locations, these systems are not integrated, although many TIM professionals understand the value of crash reports as a performance measurement. Various locations now collect the top three measurements: (1) the time a lane is closed, (2) the time that responders are at the scene, and (3) secondary crashes.

Other localities measure the number of calls or dispatches associated with a crash or other incident. For example, the Florida Department of Transportation operates a program called SunGuide®, which manages and maintains the intelligent transportation systems of the region. The program posts statistics on the use of its Road Rangers and response time on lane blockages.

Many public safety groups also track their line-of-duty deaths and number of injuries to responders who are struck while at TIM operations. The International Association of Fire Chiefs maintains a database for those who want to report near-miss incidents on a TIM operation.

In spite of many sources of data, crashes still evoke strong feelings, and "impacts" often supplement objective measures with subjective or anecdotal information to deliver a message. Occasionally, programs with effective simulation modeling tools might work out scenarios and determine the cumulative delay to anticipate challenges and to plan a response in advance.

Program managers might also use the TIM self-assessment tool to evaluate progress annually. FHWA uses the aggregate results to identify program gaps and better manage resources. In 2008 and 2011, FHWA revised the tool to incorporate performance metrics and rephrase some of the questions to better align with the National Unified Goal. Ideally, a jurisdiction will convene a TIM team meeting annually to conduct the self-assessment and revise its action plan toward established goals.

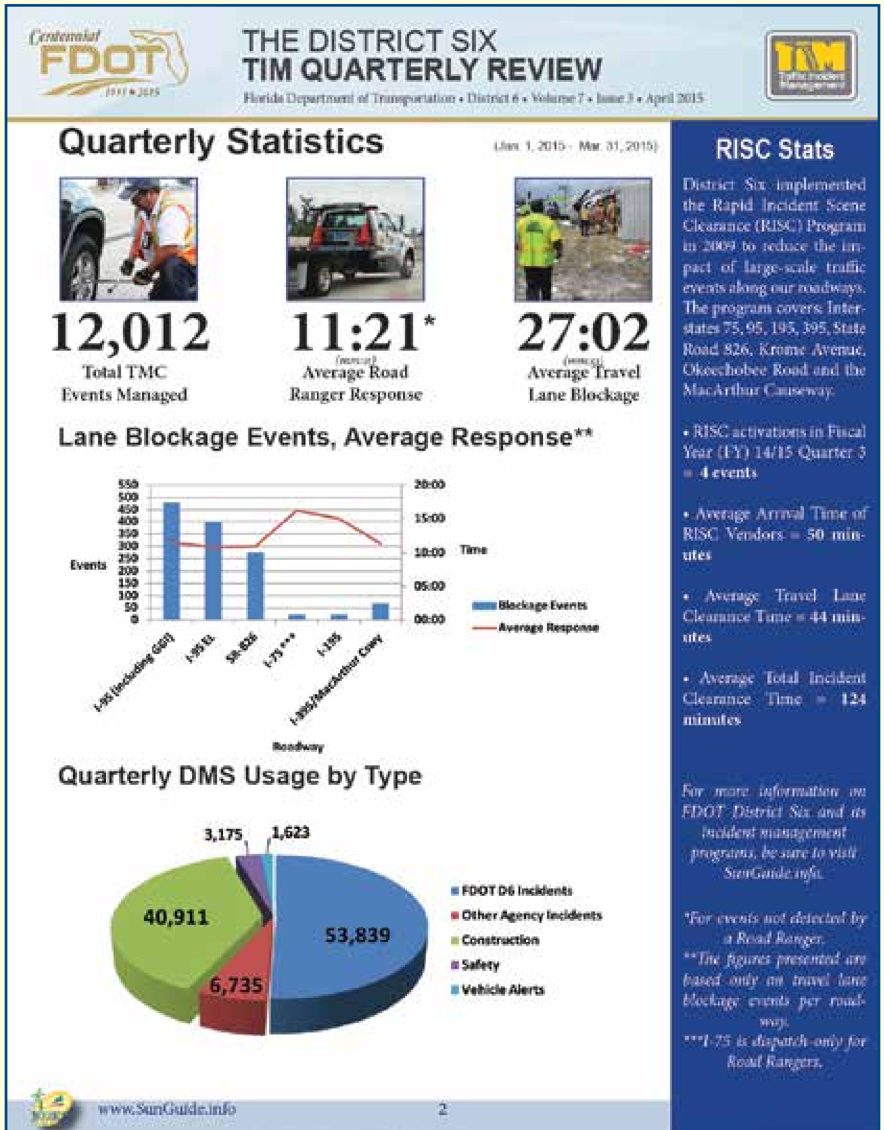
Institutionalized TIM Programs

A TIM program and its administrative coalition—the TIM team—institutionalize the program and provide critical services that support field personnel, the TIM task force. In the early years of TIM, individuals championed the call to organize those responding to traffic crashes and incidents. However, FHWA has found that only institutionalized programs survive disruptions when a champion retires or leaves, or there are changes in the political landscape.

Institutionalized programs collect performance measurement data to demonstrate the value of the program to elected officials. TIM teams manage financial, equipment, and personnel resources, as well as offer suggestions to jurisdictional leadership regarding investments and policies. The TIM administrative program develops and maintains plans. The TIM team also may be the face of TIM with the public and the media.

The most effective TIM programs have significant support elements behind all of the responders. FHWA TIM proponents believe that building and institutionalizing these programs will significantly enhance and improve TIM operations in the future. Because responders also tackle most community incidents—whether large or small—investing in the TIM program also shows dividends as public safety professionals address moderate to large-scale events with the same protocols and working relationships.

Building the institutions behind the responders is one of FHWA's principal goals over the next 5 years. In the months ahead, FHWA and State, tribal, regional, and local TIM programs will work with TIM program leaders who wish to enhance and institutionalize their operations.


Centennial FDOT 1915 • 2015

THE DISTRICT SIX
TIM QUARTERLY REVIEW

Florida Department of Transportation • District 6 • Volume 7 • Issue 3 • April 2015

Quarterly Statistics (Jan. 1, 2015 - Mar. 31, 2015)

12,012 Total TMC Events Managed

11:21* (mm:ss) Average Road Ranger Response

27:02 (mm:ss) Average Travel Lane Blockage

Lane Blockage Events, Average Response**

Quarterly DMS Usage by Type

RISC Stats

District Six implemented the Rapid Incident Scene Clearance (RISC) Program in 2009 to reduce the impact of large-scale traffic events along our roadways. The program covers: Interstates 75, 95, 195, 395, State Road 826, Krome Avenue, Okeechobee Road and the MacArthur Causeway.

- RISC activations in Fiscal Year (FY) 14/15 Quarter 3 = **4 events**
- Average Arrival Time of RISC Vendors = **50 minutes**
- Average Travel Lane Clearance Time = **44 minutes**
- Average Total Incident Clearance Time = **124 minutes**

For more information on FDOT District Six and its incident management programs, be sure to visit SunGuide.info.

**For events not detected by a Road Ranger.*
***The figures presented are based only on travel lane blockage events per roadway.*
****I-75 is dispatch-only for Road Rangers.*

www.SunGuide.info 2

Florida DOT District Six

Florida DOT's District Six routinely captures and shares performance data, as it did in this newsletter from 2015, demonstrating the value of TIM resources.

Kimberly C. Vásconez serves as team leader of the Traffic Incident & Events Management Team and director of the TIM program in FHWA's Office of Operations. She has 28 years of disaster management experience with FHWA, the U.S. Department of Homeland Security, the Federal Emergency Management Agency, and the U.S. Agency for International Development. Vásconez has a bachelor's degree in journalism from Indiana University of Pennsylvania and a master's degree in public and international administration from the University of Pittsburgh.

For more information, contact Kim Vásconez at 202-366-1559 or kimberly.vasconez@dot.gov. To learn more about FHWA's TIM program, please visit www.ops.fhwa.dot.gov/eto_tim_pse/about/tim.htm.

Along the Road

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

Policy and Legislation

FHWA Launches National Tunnel Inspection Program

The Federal Highway Administration recently published the final rule for standards that will serve as the foundation of the Nation's first tunnel inspection program. The new National Tunnel Inspection Standards (NTIS) are modeled after FHWA's successful bridge program established nearly 50 years ago to ensure the safety of U.S. bridges.

FHWA's new tunnel inspection standards require annual reports on tunnel conditions and inspection findings, such as the partially lit "DO NOT ENTER" sign in this tunnel.

Previously, FHWA provided guidance on inspections but had no means by which to require tunnel owners, such as State departments of transportation or other transportation agencies, to inspect tunnels. In addition, tunnel inspection methods have varied widely. The NTIS outline requirements and call for annual reports on tunnel condition information and inspection findings. The requirements include routine inspections of tunnels on all public roads, along with reporting data to FHWA; training and a national certification program for tunnel inspectors; and the timely correction of any deficiencies with tunnels.

With the new program, FHWA also will compile an inventory of the Nation's tunnels and begin to develop a national database similar to the National Bridge Inventory.

To support the implementation of the standards, FHWA developed several guidance documents and manuals. The agency will offer training for State and local engineers on how to conduct highway tunnel inspections, including what elements to inspect and how to code and record the results.

For more information, visit www.fhwa.dot.gov/bridge/inspection/tunnel. The final rule can be viewed at www.federalregister.gov/articles/2015/07/14/2015-16896/national-tunnel-inspection-standards.

Technical News

New York Publishes Report on Living Snow Fences

The New York State Department of Transportation (NYSDOT) released a report that explains the design, installation, and maintenance of its living snow fences, a form of passive snow control. Living snow fences—rows of vegetation such as trees, shrubs, or corn—help mitigate blowing and drifting snow, which can create hazardous driving conditions and increase the cost of highway maintenance.

Living snow fences disrupt wind patterns, causing blowing snow to be deposited in designated areas around the fence and away from the road. The vegetation performs the same function as wooden or plastic snow fences but offers potentially longer life cycles, more aesthetically pleasing features, and better returns on investment.

Mark Appleby, State University of New York College of Environmental Science and Forestry

Living snow fences, like this line of shrub willows along I–81 near Preble, NY, help protect roads from drifting snow, which can cause hazardous driving conditions.

According to NYSDOT, this research, which includes case studies featuring four demonstration sites, provides new insights on the structure and snow-trapping potential of living fences over time. The study identified key factors, such as height and porosity (the amount of open space within the snow fence), for successful implementation that have implications for the design, feasibility, and effectiveness of living snow fences.

NYSDOT incorporated information from the study into its guidelines and protocols over the course of the project. Researchers also created, tested, and revised a benefit/cost analysis tool. Example scenarios modeled using the tool showed that rows of shrub willows and other types of vegetation can reduce the cost of snow and ice control. The tool also demonstrated other benefits of living snow fences, such as reduced crash rates and improved travel speeds.

The full report is available at www.trb.org/main/blurbs/172930.aspx.

Transportation Research Board and NYSDOT

Public Information And Information Exchange

FHWA Collects New Data To Bolster Bridge Inspections

FHWA recently began collecting new data elements that will help the agency more closely monitor the condition of bridges across the country. Traditionally, inspectors reported one overall score to rate the condition of a bridge's surface. That one score would have to reflect both the severity of a problem and whether it is widespread or confined to a small area of the bridge deck. Under the new system, required in the Moving Ahead for Progress in the 21st Century Act, inspectors now will provide a separate rating for each square foot of the deck and its other elements, including joint seals. Dividing bridge components into smaller, more manageable elements ensures that engineers understand and report the extent of deterioration, which helps them make more informed decisions about repair, preservation, and replacement.

Over the last decade, even as the total number of bridges in the Nation's inventory increased by nearly 15,000 bridges—from 595,668 to 610,749—the percentage of bridges classified as structurally deficient dropped from 13.1 percent in 2005 to 10 percent in 2014.

State DOTs will continue to provide the data to FHWA's National Bridge Inspection Program. FHWA provides funding to assist States in replacing, rehabilitating, and preserving bridges. Through Federal inspection regulations and the oversight of State programs, the agency helps ensure the safety of the Nation's bridges.

FHWA has started collecting additional data to better monitor the condition of bridges, such as this one being checked by an inspection team.

Connect Historic Boston Project Breaks Ground

USDOT's Under Secretary for Policy, Peter Rogoff, joined Boston Mayor Martin Walsh and other officials recently for the groundbreaking of the Connect Historic Boston project. Construction is underway on the project, which will improve pedestrian and bicyclist access to Boston and various local historic sites.

Connect Historic Boston is an initiative between the National Park Service and Boston's Public Works and Transportation Departments. The $23 million project will use a $15.5 million Transportation Investment Generating Economic Recovery (TIGER) grant. The TIGER program funds transformative projects that help communities keep pace with expanding and diverse travel needs.

"Connect Historic Boston will make it easier for residents and visitors alike to get around easily and reduce their reliance on local roads," says Under Secretary Rogoff. "We anticipate that this project will dramatically improve Boston's historic areas and inspire similar projects in cities across the country."

The project reconstructs and widens an inadequate, aging system of paths and sidewalks along Joy Street, Constitution Road, and the Blackstone Block, between Haymarket and Faneuil Hall. The new bike trail around downtown will feature buffered, protected bike lanes, special paving to separate the trail from the roadways and pedestrian walkways, and two-lane tracks for cyclists. The trail also will better connect cyclists with other paths and transit stations throughout the area.

For more information, visit www.cityofboston.gov/publicworks/connecthistoricboston.

NHTSA Releases Crash Data Related to School Transportation

The National Highway Traffic Safety Administration recently released a fact sheet on the number of people killed annually in crashes related to school transportation. These crashes are ones that involve, either directly or indirectly, a school bus or similar vehicle transporting children to or from school or related activities.

School-Transportation-Related Crashes (DOT HS 812 170) presents 10 years of data, from 2004 to 2013. The fact sheet includes data aggregated by age group, time of day, fatalities, impact point and crash type, vehicle maneuver, and person type (such as driver, passenger, or pedestrian).

Between 2004 and 2013, 340,039 motor vehicle crashes resulted in fatalities. Of those, 1,214, or 0.4 percent, were classified as related to school transportation. Those crashes accounted for 1,344 fatalities—an average of 134 people killed per year. Occupants of school vehicles accounted for 8 percent of the fatalities, and nonoccupants (pedestrians, bicyclists) accounted for 21 percent of the fatalities. Most—71 percent—of the people who lost their lives in these crashes were occupants of other vehicles involved.

Over the same period, there were 327 school-age children (defined in the fact sheet as age 18 or younger) who died in school-transportation-related crashes. Of these, 54 were occupants of school transportation vehicles, 147 were occupants of other vehicles, and 116 were pedestrians. About two-thirds of the school-age pedestrian fatalities resulted from strikes by school buses or vehicles functioning as school buses.

The fact sheet is available at www-nrd.nhtsa.dot.gov/Pubs/812170.pdf.

FHWA Awards Grants for Pricing Pilot Programs

FHWA recently announced nearly $3.4 million in grants for States and local agencies to explore innovative new pricing approaches to reduce traffic congestion, overcrowding of transit systems, and parking shortages during peak travel times. The grants are part of FHWA's Value Pricing Pilot Program to fund the study of new pricing methods.

Since its creation more than two decades ago, the Value Pricing Pilot Program has funded more than 50 cutting-edge projects to tackle congestion in major metropolitan areas. Many of those approaches, such as high-occupancy toll lane conversions, have become commonplace nationwide.

Lake Tahoe Transportation District

The Tahoe Transportation District received a grant for a parking pricing project to help address uncontrolled parking in the congested areas along State Route 28 near Lake Tahoe, NV. Ad hoc parking creates dangerous travel conditions and unsafe pedestrian access to popular beaches and recreation areas.

The grants support five forward-looking projects in California, Nevada, and Texas. Three projects are located in California. One aims to reduce drive-alone trips on the campus of the University of California at Berkeley. Another will provide user incentives in San Francisco to shift travel times and routes away from overcrowded Bay Area Rapid Transit stations to improve system performance. The third grant goes to a project in Los Angeles to evaluate "cordon pricing," which involves charging vehicles for entry into congested areas.

In Nevada, the Lake Tahoe Transportation District received a grant for a parking pricing project to minimize car travel through the most congested areas around the lake. Grant funding will also support a pay-as-you-drive insurance pilot managed by the Texas A&M Transportation Institute. This pilot will charge users according to mileage driven instead of a flat rate.

For more information, visit http://ops.fhwa.dot.gov/congestionpricing/value_pricing.

MassDOT Launches Program To Give Youth Transit Passes

Massachusetts Department of Transportation (MassDOT) Secretary and Chief Executive Officer Stephanie Pollack recently announced a year-long pilot program to provide monthly transit passes at a reduced cost to up to 1,500 youth between the ages of 12 and 21 in the cities of Boston, Chelsea, Malden, and Somerville.

The partnership between the Massachusetts Bay Transportation Authority (MBTA) and the cities is designed to expand the number of student passes available through some middle and high schools to a larger population of young people within the transit agency's service area.

The program was developed by a working group of MassDOT, MBTA, youth advocates, and municipal partners who met for 8 months to discuss the transportation access needs identified by the youth. The pilot will measure costs to the MBTA and the benefits to the youth, including their ability to access jobs, school, and civic opportunities. To measure the program's impact, participants (and their guardians) must sign consent forms agreeing to anonymous data collection on their use of the transit system.

The passes will be administered by municipal partners rather than by schools. The youth pass is a LinkPass valid on local buses and the subway system and will cost $26 a month or $7 for a 7-day pass (7-day pass availability depends on the city partner). Residents between the ages of 19 and 21 must meet needs-based criteria by demonstrating enrollment in high school, a GED® or other education program, job training, or a State or Federal benefit program.

For more information, please visit www.mbta.com/youthpass.

MassDOT

Caltrans and Partners Complete $1.1 Billion Presidio Parkway

FHWA recently celebrated the opening of San Francisco's long-awaited Presidio Parkway with State and local officials. The $1.1 billion project was a joint effort between the California Department of Transportation (Caltrans), the San Francisco County Transportation Authority, the National Park Service, and other partners. The project relied on $363 million in Federal funds, as well as $152.5 million from the American Recovery and Reinvestment Act, and a $150 million Transportation Infrastructure Finance and Innovation Act loan.

Since work began in 2009, the Presidio Parkway project replaced Doyle Drive, a 1.6-mile (2.6-kilometer) segment of SR–101 linking the city to the Golden Gate Bridge, connecting Marin and San Francisco Counties, and providing a major regional traffic link between the peninsula and North Bay Area counties.

Built in 1936, Doyle Drive outlasted its useful life, was seismically deficient, and no longer met highway standards. Though planning for this project began in the 1950s, the vulnerability of this important route became strikingly apparent during the Loma Prieta earthquake in 1989, which killed 63 people, injured thousands, collapsed segments of I–880, and caused widespread traffic problems for months.

The Presidio Parkway, shown here (red arrow) adjacent to the coastline, is a critical link between San Francisco and Marin Counties and the Golden Gate Bridge.

The Presidio Parkway offers drivers a spectacular regional gateway between the Golden Gate Bridge and downtown San Francisco, and USDOT's Build America Transportation Investment Center highlights the project as an example of a successful public-private partnership that can serve as a model for other projects. The center is a resource for State and local governments, developers, and investors seeking innovative financing strategies for their transportation infrastructure projects.

New Criteria Will Improve Prioritization of Capital Projects

An independent Project Selection Advisory Council in Massachusetts recently published new recommendations for the evaluation and prioritization of proposed capital projects. The council worked for 18 months to develop a new process for selecting transportation investments, and submitted recommendations to MassDOT. Throughout the period of its work, the 8-member council held 12 public meetings and 6 public hearings across the Commonwealth.

The Massachusetts Legislature established the council in 2013 and charged it with developing a uniform, data-driven, and transparent approach to scoring and ranking capital transportation projects for funding. The new process, which MassDOT will begin to implement immediately, seeks to ensure that transportation dollars are spent in a multimodal and strategic manner and are distributed in a regionally balanced way.

The recommended evaluation process applies to two types of projects: (1) modernization projects, which replace and rehabilitate existing transportation assets, and (2) capacity projects, which add new transportation capacity or expand existing connections. Projects will be ranked according to a weighted formula that takes into account cost-effectiveness, economic impact, environmental and health effects, mobility, safety, social equity, and system preservation.

The Project Selection Advisory Council's report has been filed with the Legislature, and implementation of the criteria will begin with the development of the fiscal year 2017–2021 capital investment plans for MassDOT and the MBTA. The council will continue to advise and assist with implementation of the recommendations.

For more information, visit www.mass.gov/massdot/projectselection.

MassDOT

by Carrie Boris

Your Home for Accessing ITS Data

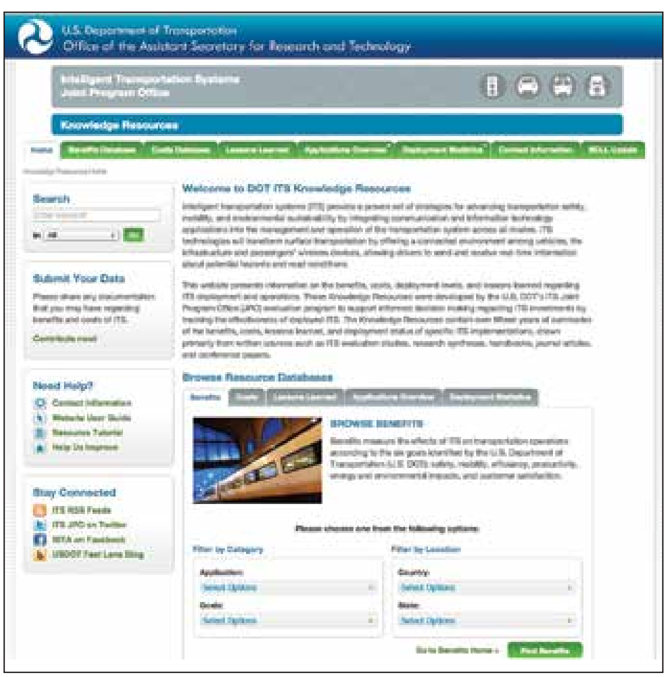
How do you manage more than 15 years' worth of data and turn it into a valuable resource for transportation professionals? The U.S. Department of Transportation was faced with this challenge to organize and store data resulting from intelligent transportation systems (ITS) projects. The agency understood that it was critical to track benefits, costs, lessons learned, and implementation status in order to advance ITS programs.

To meet the need for storing, organizing, and providing access to these data in a useful way, USDOT maintains the ITS Knowledge Resources Web site at www.itskrs.its.dot.gov. The site presents information on ITS deployment and operations, drawn primarily from sources such as ITS evaluation studies, research syntheses, handbooks, journal articles, and conference papers.

An Update-to-Date Resource

Developed and maintained by the ITS Joint Program Office, the site launched in 1999 with information on costs and benefits. In 2003, developers added data from surveys on ITS deployment statistics and, in 2005, launched a database of lessons learned.

The ITS Joint Program Office generally adds new content on a monthly basis to keep the site up to date. Data on deployment status are updated every 2 to 3 years as new survey results become available. The latest major update to the site, in November 2014, included the release of the *Intelligent Transportation Systems Benefits, Costs, and Lessons Learned Update Report* (FHWA-JPO-14-159) and an upgrade to the deployment statistics.



"The goal is to help State, regional, and local transportation professionals considering ITS in the development of transportation plans and projects to address local transportation needs," says Marcia Pincus, a program manager in the ITS Joint Program Office. "It also benefits researchers to better understand the state of knowledge and extent of deployment of ITS."

Three Key Databases

The databases of benefits, costs, and lessons learned are the heart of the Web site. Each database includes overview pages, mapping functions to search by location, and lists of the latest updates, frequently asked questions, and related documents.

Benefits database. This resource offers data measuring the effects of ITS on transportation operations according to the six goals identified by USDOT: safety, mobility, efficiency, productivity, energy and environmental impacts, and customer satisfaction. The database presents findings from ITS evaluations in a concise summary format that includes a statement of the evaluation finding, context narrative, and identifying information such as date, location, and source, as well as the evaluation details that describe how researchers determined the benefits. Site users can browse or search the benefit summaries by application, goal area, or location.

Costs database. This database provides cost estimates for ITS deployments. Users can access information about either system costs or unit costs. Systems consist of multiple ITS elements and typically represent the total cost of an ITS project or a portion of a project. Each entry describes the background of the project, lists the ITS technologies deployed, and presents the costs and what the costs covered. Unit costs are for an individual ITS element, such as a dynamic message sign. The database presents a cost range as well as an estimate of the length in years of the element's usable life.

"This information helps planners develop project cost estimates during the planning or preliminary design phase, for policy studies, and for cost-benefit analyses," says Pincus. "To provide a complete picture, both nonrecurring capital costs and recurring operating and maintenance costs are included whenever possible."

Lessons learned database. Lessons learned capture the real-life experiences of practitioners in planning, deploying, operating, and evaluating ITS projects, which can help improve the effectiveness of future projects. Each description includes recommendations, narratives, and identifying information such as date, location, and contact. Lessons are collected primarily from ITS case studies, best practice compendiums, planning and design reviews, and evaluation studies. The lessons contained in this knowledge resource, however, should not be considered official policy or guidance from USDOT.

For more information, contact Marcia Pincus at marcia.pincus@dot.gov or 202-366-9230.

Carrie Boris is a contributing editor for PUBLIC ROADS.

Training Update

by Jason Dietz and Vanessa Almony

Advancing Asphalt Recycling

Departments of transportation face increasing challenges from tightening budgets and deteriorating roadway conditions on aging infrastructure. To overcome these challenges, State DOTs are looking for ways to assess and modernize their approach to maintaining and managing highway investments.

Using recycled materials can help highway agencies improve their bottom lines—and protect the environment by conserving natural resources and energy. The Federal Highway Administration considers recycling a viable alternative to traditional rehabilitation techniques for asphalt-surfaced pavements. For many projects, in-place recycling and reuse offers an environmentally preferable and cost-effective solution compared to other reconstruction alternatives.

Training to Help You Get It Right

The National Highway Institute's course 131050, Asphalt Pavement In-Place Recycling Techniques, is a 2-day, instructor-led session designed to give DOT staffers the knowledge they need to use these techniques successfully. The course is intended for State and local transportation agency engineers and those responsible for selecting, designing, or constructing projects for asphalt pavement maintenance, resurfacing, rehabilitation, and reconstruction alternatives.

Prior to attending the classroom portion, participants complete two Web-based modules that introduce techniques for pavement evaluation, potential recycling methods, and the types of equipment commonly used for each. The classroom session focuses on project and technique selection and justification, materials considerations and mix designs, construction specifications, and project control considerations during construction.

"Course participants also are better prepared to support their agencies as they align with [the Moving Ahead for Progress in the 21st Century Act], which encourages a focus on performance management and pavement measures," says Timothy Aschenbrener, a pavement and materials engineer with FHWA's Resource Center.

Participants engage in small- and large-group activities to explore current in-place recycling technologies and learn their benefits and factors for successful use. The course is particularly suited to those who are responsible for selecting and designing asphalt in-place recycling projects, writing effective specifications, and inspecting projects during their construction. Contractors, consulting engineers, and industry representatives involved in in-place recycling also can benefit from this course.

Understanding the Benefits

Instructors underscore the benefits of recycling, known as the three E's:

A construction crew uses in-place recycling equipment, shown here, beside a stockpile of reclaimed asphalt pavement.

Environment: Promoting recycling as the first option to consider during planning encourages environmental stewardship. In-place recycling can reduce construction-related greenhouse gases as compared to conventional mill and overlay strategies by more than 50 percent, and asphalt pavement is up to 100 percent recyclable.

Economics: The cost of in-place recycling is 40 percent to 60 percent of the cost of conventional mill and overlay strategies. Savings come from reusing existing materials and avoiding the costs of milling and removing materials from the site, as well as eliminating dumping fees.

Engineering: Using good engineering design helps to assure longer life of pavements and highway assets. By treating existing distress, pavement life may be lengthened by 3 to 5 years compared to conventional strategies such as leveling courses or mill and overlay combinations.

"Although in-place pavement recycling has been used since the early 1900s," says Aschenbrener, "the technology has advanced sufficiently to make it more practical today." NHI's course aims to help transportation agencies better understand how and when to use in-place recycling, advancing its use and acceptance.

For more information, visit NHI's Web site at www.nhi.fhwa.dot.gov.

Jason Dietz is a pavement and materials engineer in FHWA's Resource Center and is an NHI instructor.

Vanessa Almony is a contracted instructional systems designer with NHI.

2016 Price Changes for NHI's Web-Based Courses

On January 1, 2016, NHI will begin charging a small fee for the Web-based training courses developed through a partnership with the Transportation Curriculum Coordination Council (TCCC). Courses will cost $25 to $50 depending on duration. NHI's Web-based prerequisite courses and those taken in conjunction with blended instructor-led training continue to be available at no cost. For pricing, please view the course details on the NHI Web site.

Participants who enroll in Web-based training will have access to the course for 6 months. After that time, participants need to reregister for the course to access or complete the training. For more information and frequently asked questions, visit www.nhi.fhwa.dot.gov.

Communication Product Updates

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

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

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

National Technical Information Service
5301 Shawnee Road
Alexandria, VA 22312
Telephone: 703–605–6000
Toll-free number: 1–888–584–8332
Web site: www.ntis.gov
Email: customerservice@ntis.gov

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

R&T Product Distribution Center
Szanca Solutions/FHWA PDC
13710 Dunnings Highway
Claysburg, PA 16625
Telephone: 814–239–1160
Fax: 814–239–2156
Email: report.center@dot.gov

For more information on R&T communications products available from FHWA, visit FHWA's Web site at www.fhwa.dot.gov, the FHWA Research Library at www.fhwa.dot.gov/research/library (or email fhwalibrary@dot.gov), or the National Transportation Library at ntl.bts.gov (or email library@dot.gov).

Synthesis of Geosynthetic Reinforced Soil (GRS) Design Topics (Report)
Publication Number: FHWA-HRT-14-094

Geosynthetic reinforced soil (GRS) technology consists of closely spaced layers of geosynthetic reinforcement and compacted granular fill material, used for a variety of earthwork applications. This report features six topics related to GRS design, as differentiated from mechanically stabilized earth design. Those topics include: (1) embedment length, (2) pullout check, (3) eccentricity, (4) lateral pressures, (5) the equation for soil geosynthetic capacity for bearing resistance and required reinforcement strength, and (6) long-term geosynthetic reduction factors. The report includes a research summary of each topic and provides discussions of pertinent issues related to current practice.

Embedment length refers to the length of reinforcement within the GRS mass. This synopsis includes a review of research and case histories on the use and performance of shorter reinforcement lengths.

The report discusses the implications of performing or not performing the design check for reinforcement pullout of a GRS structure. The pullout check is intended to ensure adequate reinforcement length to prevent a structure from failing due to load and pressure—causing the reinforcements to pull out of the soil, for example. The report covers the history, research, and performance data and their impact on the requirement for pullout for GRS design.

Eccentricity, also referred to as overturning, is a principal component in the design of certain concrete walls with relatively rigid footings. This report details the purpose and theoretical justification of eliminating the need to limit eccentricity considering the flexible nature of GRS.

Lateral pressures against a GRS face include soil compaction, the movement of the facing, and the spacing of the reinforcement. This synopsis covers the effects of compaction-induced stresses on the internal lateral stress of both unreinforced and reinforced soil. Researchers discuss measured thrusts against facing elements and compare methods for estimating this thrust with measured values.

The researchers also discuss how to use the soil geosynthetic equation to estimate the bearing resistance and required reinforcement strength of GRS walls and abutments. The equation uses an empirical W-term, or factor, that accounts for the reinforcement spacing and maximum aggregate size in a structure.

Lastly, the report examines long-term strength reduction factors and discusses differences between current practices for GRS and mechanically stabilized earth design. This topic includes a summary of the research and the associated theory behind the reduction factors of creep, degradation (or durability), and installation damage.

The report is available to download at www.fhwa.dot.gov/publications/research/infrastructure/bridge/14094/index.cfm. Printed copies are available from the PDC.

Factors Influencing Operating Speeds and Safety on Rural and Suburban Roads (Report)
Publication Number: FHWA-HRT-15-030

Drivers who exceed the speed limit or drive too fast for the road conditions are involved in nearly one-third of all fatal crashes. More than 10,000 people are killed in speed-related crashes each year. This report documents the component factors affecting speed and safety on rural and suburban roadways that are not limited access. The report also describes treatments that have the potential to reduce speed-related crashes.

The first phase of the study included a review of literature on design features and current practices associated with safer operating speeds and identification of treatments for field evaluations. The second phase evaluated treatments to determine their effectiveness in reducing speeds on two-lane horizontal curves in rural and suburban areas. The study assessed high-friction surface treatments, optical speed bars, and various combinations of lane and shoulder widths.

Researchers evaluated high-friction surface treatments at four sites compared with three control sites in West Virginia. The analysis confirmed that friction increased. However, speed and encroachment analyses revealed no consistent differences between the periods before and after applying the treatment. These inconclusive findings mean that further research is needed. Currently, FHWA is conducting an observational before-and-after safety evaluation under a separate project, “Evaluations of Low Cost Safety Improvements Pooled Fund Study.”

Optical speed bars are short transverse stripes along the edges of a lane spaced at gradually decreasing distances. They are intended to increase drivers’ awareness of speed and so cause them to reduce speed. Researchers implemented and evaluated the stripes at eight sites in Alabama, four in Arizona, and seven in Massachusetts. They tested two different designs and found inconsistent speed reductions at all test sites, concluding that the designs used in this study were unsuccessful in reducing vehicle speeds.

The researchers also estimated the safety effects of combinations of lane width and shoulder width on rural two-lane, two-way road segments in Illinois and Minnesota. Although they found it difficult to distinguish differences in the performance of an 11-foot (3.4-meter)-wide lane compared to that of a 12-foot (3.7-meter)-wide lane, increasing the shoulder width did decrease the expected total number of crashes (all types and severities). When they studied the interaction of lane width and shoulder width, the researchers found that shoulder width has the greatest effect on safety when the lane width is 10 feet (3 meters). The effect of shoulder width lessens as lane width increases.

This report is available to download at www.fhwa.dot.gov/publications/research/safety/15030.

Strength Characterization of Open-Graded Aggregates for Structural Backfills (Report)
Publication Number: FHWA-HRT-15-034

Open-graded aggregates are compacted aggregates with relatively large void spaces not filled with intermediate-sized particles. These aggregates are becoming more common in road and bridge construction because they are easy to place, require simple quality assurance testing, and have the advantages of very low fine particle content, lighter unit weight, free-draining characteristics, and low frost heave potential.

State and local transportation agencies frequently use crushed, manufactured open-graded aggregates as structural backfill material for retaining walls, bridge foundations, and other ground improvement applications. However, the strength characteristics of these materials are not fully understood or applied. Designers need to know the friction angle to account for lateral earth pressures and bearing resistance. But because of the large size of the standard American Association of State Highway and Transportation Officials (AASHTO) open-graded aggregates, this parameter cannot be measured with standard testing equipment. Instead, current practice is to select aggregates with low default friction angles, which can lead to overly conservative, less cost-effective designs.

This report discusses a study to establish a knowledge base featuring the most commonly used AASHTO open-graded aggregates. The study included a systematic approach to fully characterize the strength parameters using a large-scale direct shear and triaxial device in FHWA’s geotechnical laboratory at the Turner-Fairbank Highway Research Center. The researchers also investigated relationships between other important soil parameters and the friction angle, as well as the effect of different automated testing devices and methods to interpret the data.

The report presents strength characteristics of 16 open-graded aggregates representative of commonly selected structural backfills. The test results indicate higher strengths for these materials than current default values typically assume in design. Aside from strength, researchers measured gradation, density, repose angle, angularity, and texture. They also examined correlations between various soil properties and strength parameters and found that the mean grain size, sphericity, angularity, and void ratio play a role in the measured friction angles.

The document is available to download at www.fhwa.dot.gov/publications/research/infrastructure/structures/bridge/15034/index.cfm.

Foundation Characterization Program (FCP): TechBrief #1—Workshop Report on the Reuse of Bridge Foundations (TechBrief)
Publication Number: FHWA-HRT-14-072

This technical brief presents the results of a workshop on the reuse of bridge foundations held in 2014 at the Transportation Research Board's 93rd Annual Meeting. The workshop was part of ongoing efforts by FHWA to identify needs for research and development with respect to FHWA's Foundation Characterization Program. The program includes the development and evaluation of methodologies for characterizing existing bridge foundations for the determination of unknown geometry, material properties, integrity, and load-carrying capacity.

Workshop participants identified reuse applications for bridge foundations, including replacing the superstructure of an existing bridge because of structural deterioration, widening an existing bridge, repurposing (for example, using an existing railroad bridge foundation for a pedestrian/bicycle path), and reuse with strengthened foundation and accelerated bridge construction methods.

The reuse of existing foundations faces many challenges. Evaluating an existing bridge foundation for reuse is a multidisciplinary task that calls for structural, hydraulic, geotechnical, and construction expertise. Workshop presenters recognized that the most important need for advancing the reuse of bridge foundations is development of FHWA best practices and technical guidance for evaluating existing foundations and mitigating the risks involved.

The technical brief is available to download at www.fhwa.dot.gov/publications/research/infrastructure/structures/bridge/fcp/14072/14072.pdf.

Investigating Improvements to Pedestrian Crossings with an Emphasis on the Rectangular Rapid-Flashing Beacon (Report)
Publication Number: FHWA-HRT-15-043

The rapid-flashing beacon has received national attention as a way to emphasize the presence of a pedestrian crossing the roadway, but practitioners have asked whether the shape of the beacon plays a role in its effectiveness. This report documents an FHWA project that investigated how characteristics of rapid-flashing beacons (shape, size, and brightness) affect the ability of drivers to detect people or objects along the roadway and the likelihood of drivers yielding to a pedestrian.

In the first phase of the project, researchers reviewed recent literature and crash data to identify trends in pedestrian safety and in the effectiveness of crossing treatments. They also conducted limited field observations at 10 crosswalks in 5 States as a source of ideas for evaluating crossings in the second phase of the project.

Research in the second phase included a closed-course study and an open-road study to determine what characteristics of rapid-flashing beacons affected drivers' ability to detect people or objects, as well as drivers' likelihood of yielding to a pedestrian. The closed-course study included 71 participants who drove the course and viewed 8 beacon assemblies, 9 distractor signs, and up to 11 roadside objects. The open-road study involved both circular and rectangular beacons installed at 12 sites located in 4 cities: Austin and College Station, TX; Flagstaff, AZ; and Milwaukee, WI.

Although the researchers found a slight difference between the average percentage of drivers yielding to circular versus rectangular beacons (daytime: 67 percent and 59 percent, respectively; nighttime: 69 percent and 72 percent, respectively), the statistical evaluation determined that the shape of the beacon did not have a significant effect on drivers' responses. However, the results showed that a driver is more than three times as likely to yield when a beacon is activated as when it is not activated. Other variables that had an impact on yielding included beacon intensity (for nighttime) and city (yielding was higher in Flagstaff, AZ, compared with the other cities included in study).

The document is available to download at www.fhwa.dot.gov/publications/research/safety/15043/index.cfm.

Reporting Changes of Address

PUBLIC ROADS has two categories of subscribers. One includes the organizations and people who receive the magazine without charge; the editorial office of the magazine maintains the mailing list for this group. The other category is the group of people and companies that pay to receive the magazine; the mailing list for this group is maintained by the Superintendent of Documents for the U.S. Government Printing Office.

Free copies are distributed to offices of the Federal Highway Administration, State highway agencies, technology transfer centers, and selected leaders who have responsibility for highway-related issues. Most of these copies are mailed to offices for their internal distribution or to people by position title rather than by name. If any office or individual subscriber in this category has a change of address, please send the complete previous mailing address and the complete new address to our distribution manager, Lisa Shuler, via email (lisa.shuler@dot.gov), telephone (202–493–3375), or mail [Lisa Shuler, PUBLIC ROADS Distribution Manager (HRTM), Federal Highway Administration, 6300 Georgetown Pike, McLean, VA, 22101-2296].

Paid subscribers who have an address change should notify the U.S. Government Printing Office, Claims Office, Washington, DC, 20402; or call 202–512–1800; or fax 202–512–2168. Please do not send an address change for a paid subscription to the editorial office of PUBLIC ROADS. We do not manage the paid subscription program or mailing list, and we are not able to make the requested change.

National Program Aims To Improve Tunnel Safety

New standards set the bar for comprehensive inspections.

Tunnels are integral to the Nation's system of public roads. They enable the crossing of barriers, increased mobility, and efficient transportation of goods and services. In the Moving Ahead for Progress in the 21st Century Act, Congress declared that tunnel safety is paramount. The Federal Highway Administration has developed the National Tunnel Inspection Standards (NTIS) to promote uniform and consistent procedures for safety inspection and inventory.

Published in the *Federal Register* on July 14, 2015, the NTIS include the following key components:

- National Tunnel Inventory
- Defined inspection intervals
- Mandatory requirements for addressing critical findings
- Certification of tunnel inspectors

U.S. Department
of Transportation
Federal Highway
Administration
Attn: HRTM
1200 New Jersey Avenue, SE
Washington, DC 20590

Official Business
Penalty for Private Use $300

PERIODICALS

POSTAGE & FEES PAID

FEDERAL HIGHWAY
ADMINISTRATION

ISSN NO. 0033-3735

USPS NO. 516-690

FHWA-HRT-16-001
HRTM-20/11-15(5M200)E