Public Roads

www.fhwa.dot.gov

May/June 2013

Highways and Health
SHRP2: Behind the Wheel
What Carmaggedon?

U.S. Department of Transportation
Federal Highway Administration

Public Roads

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

May/June 2013 www.fhwa.dot.gov Vol. 76, No. 6

Articles

Trip Traces *by Mark Fitzgerald* 2

To improve safety, the SHRP2 Naturalistic Driving Study is collecting data on what happens when people crash, experience a near-crash—or drive without incident.

The Road Not Taken *by Judy Gish* 10

Here's how Los Angeles survived and thrived during two weekend closures of its busiest freeway.

Using Risk to Drive Safety Investments *by Howard Preston, Richard Storm, Karen Scurry, and Elizabeth Wemple* 16

Applying a systemic approach can help States get the biggest bang for their buck in reducing crashes.

A Bridge to Greater Connectivity *by Mark Studt and Alan Woodmansey* 24

While designing a much-needed interchange, Montana called in the cavalry—experts in accelerated bridge construction—to discuss state-of-the-art methods to avoid a long-term closure.

How Does Transportation Affect Public Health? *by Eloisa Raynault and Ed Christopher* 28

Organizations across the country increasingly are looking at the important relationship between the two disciplines.

Shouldering the Load *by Gregory M. Jones* 35

The use of paved shoulders as temporary travel lanes adds capacity when it's needed most.

Bridging the Digital Divide *by Paul R. Burley* 40

The challenges of information accessibility have prompted efforts to digitize backlogs of transportation resources currently in analog formats.

Page 2

Page 10

Page 28

Departments

Guest Editorial 1
Along the Road 46
Internet Watch 49
Training Update 50
Communication Product Updates 51

Front cover—A worker is torch-cutting rebar that was exposed during demolition of the old Mulholland Bridge in Los Angeles County, CA. The project required a weekend closure of a segment of the busy I–405 freeway. An aggressive public outreach campaign helped the California Department of Transportation (Caltrans) and its partners to complete the project without major disruptions to local traffic. For more information, see "The Road Not Taken" on page 10 in this issue of PUBLIC ROADS. *Photo by Caltrans.*

Back cover—Shown is the Carolina Bays Parkway as it crosses over the Conway Bypass near Myrtle Beach, SC. A digitized plan for construction of this segment of the Conway Bypass is part of Plans Online, the South Carolina Department of Transportation's (SCDOT) database of highway construction plans. For more information and to view the digitized plan, see "Bridging the Digital Divide" on page 40 in this issue of PUBLIC ROADS. *Photo by Rob Thompson, SCDOT.*

U.S. Department of Transportation
Federal Highway Administration

U.S. Department of Transportation
Ray H. LaHood, *Secretary*

Federal Highway Administration
Victor Mendez, *Administrator*

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

Paula Magoulas, *Editor-in-Chief*

Paula Magoulas, *Publication Manager, Creative Director*

Norah Davis, *Editor*

John J. Sullivan IV, *Associate Editor*

Paula Magoulas, *Distribution Manager*

Editorial Board
J. Paniati, chairman; J. Baxter, J. Curtis, D. Elston, T. Furst, J. Lindley, A. Lucero, R. McElroy, G. Shepherd

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: 202–493–3398. Fax: 202–493–3475.
Email: paula.magoulas@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

A Holistic Approach to Roadway Safety

More than 32,000 people lost their lives in motor vehicle crashes in the United States in 2011. Because these crashes are often the result of multiple contributing factors, the solutions to saving lives must involve a comprehensive, collaborative effort spread across the four "E's"—engineering, enforcement, education, and emergency response.

The current surface transportation legislation, Moving Ahead for Progress in the 21st Century Act (MAP-21), embraces this approach. It requires coordination among Federal safety programs on enhanced strategic highway safety plans and new requirements for performance management. Strategic highway safety plans establish a common vision for safety within a State and serve as a guide for decisions about investments in roadway safety. Therefore, States should develop the plans in collaboration with all safety partners, taking into consideration available data, knowledge, and resources during the decisionmaking process and then expending resources in the areas that are most likely to achieve the desired results.

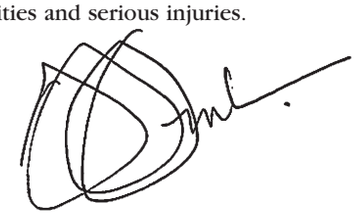
Strategic objectives and emphasis areas are actualized in States' highway safety plans, commercial vehicle safety plans, and transportation improvement plans, and in metropolitan planning organizations' transportation improvement plans. Three performance measures—number of fatalities, fatality rate, and number of serious injuries—common to the Federal Highway Administration's (FHWA) Highway Safety Improvement Program and the National Highway Traffic Safety Administration's (NHTSA) highway safety program further reinforce the linked efforts. State agencies need to coordinate their programmatic efforts and identify, prioritize, and implement life-saving strategies that enable them to set and meet common targets for safety performance.

Applying a holistic approach to improving safety at the programmatic level involves use of more comprehensive methods for developing safety solutions. Road safety audits are one example of a broader based, multidisciplinary tool available for States to use to diagnose and solve safety problems. Another is the systemic approach to planning safety improvements. The systemic approach represents an expansion in thinking beyond the traditional site analysis approach, which focuses only on making

improvements at high-crash locations. By contrast, the systemic approach looks to apply safety improvements at sites across a transportation network with the greatest potential for crashes associated with high-risk roadway features. For more on the systemic approach and how some States are incorporating it into their planning processes, see "Using Risk to Drive Safety Investments" on page 16 in this issue of PUBLIC ROADS.

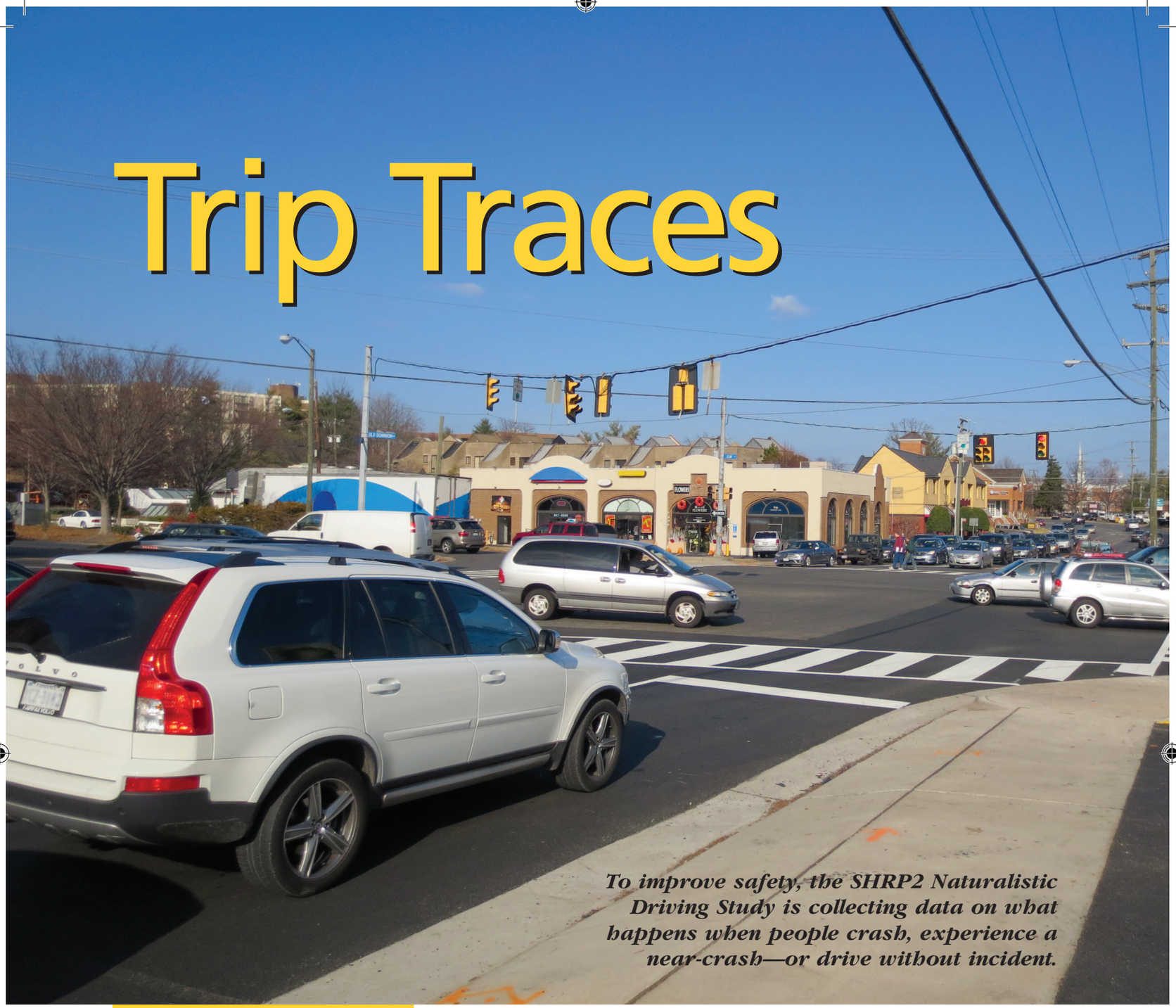
NHTSA's *Countermeasures That Work: A Highway Safety Countermeasure Guide for State Highway Safety Offices* and FHWA's Crash Modification Factors Clearinghouse can help safety professionals identify the most effective strategies and countermeasures. Both resources underscore the effectiveness of using a variety of strategies to improve highway safety, including FHWA's proven safety countermeasures and safety-related Every Day Counts initiatives. When prioritizing projects for implementation, agencies should consider which projects will maximize opportunities to advance safety. Additional information is available at www.fhwa.dot.gov/map21 and http://safety.fhwa.dot.gov.

Overall, a holistic approach affords the greatest opportunity to advance safety by ensuring support for the strategies most likely to reduce the number of fatalities and serious injuries.



Tony Furst
Associate Administrator
Office of Safety
Federal Highway Administration

Trip Traces



To improve safety, the SHRP2 Naturalistic Driving Study is collecting data on what happens when people crash, experience a near-crash—or drive without incident.

by Mark Fitzgerald

(Above) In 2008, crashes at intersections like this one accounted for about 40 percent of an estimated 5.8 million crashes nationwide, according to NHTSA, even though intersections make up a small fraction of the overall roadway miles. The SHRP2 Naturalistic Driving Study is collecting data on participants' driving behavior at intersections to help shed light on possible countermeasures.

Excessive speed, poor gap judgment, inept evasive action, in-attention, distraction—drivers are human and make mistakes.

For a long time, the transportation safety community has known that driving behavior is a leading factor in roadway crashes. In the report, *Tri-Level Study of the Causes of Traffic Accidents*, released by the U.S. Department of Transportation (USDOT) in 1979, human factors are cited as the probable cause of 93 percent of crashes. But the gap remains wide between knowing about unsafe driving behavior and being able to do something about it through countermeasures such as engineering, enforcement, public information, and education.

"We still have a long way to go before we completely understand driver distraction, drowsy driving, and speeding behavior," says Richard Compton, director of USDOT's National Highway Traffic Safety Administration's (NHTSA) Office of Behavioral Safety Research. "We definitely need a better understanding of why drivers underestimate the risks involved in these behaviors. Driver distraction, for

example, entails different types of risks in terms of manual, visual, and cognitive forms of distraction."

Reducing crashes by just 1 percent would prevent 330 deaths and save approximately $2 billion annually in medical expenses, according to a 2000 NHTSA report. In addition, crashes are a leading cause of traffic congestion. In 2011, congestion caused urban Americans to travel 5.5 billion hours more and to purchase an extra 2.9 billion gallons of fuel for a congestion cost of $121 billion, according to the *2012 Urban Mobility Report* of the Texas A&M Transportation Institute. Today, roads are more congested than ever, cars have more bells and whistles, and drivers have cell phones and other distractions at their fingertips.

"The drivers of today are very different [from] the drivers of yesterday," points out David Shinar, who serves on the Strategic Highway Research Program's (SHRP2) Safety Technical Coordinating Committee and is a professor of human performance management at Ben-Gurion University of the Negev in Israel. "If the only thing we do is drive, we think we're wasting time. We've gotten spoiled by all the available entertainment systems in the car."

These factors certainly influence driving behavior—but how exactly and to what degree? Having data that show what happens when people crash, when they experience a near-crash, and when they drive without incident could spur significant improvements in highway safety. The second SHRP2 Naturalistic Driving Study is aimed at doing just that.

Studying Driving Behavior

Established in 2006, SHRP2 aims to accelerate the renewal of the Nation's highways; improve highway safety; advance reliable travel times; and provide highway capacity in support of U.S. economic, environmental, and social goals. The program is administered by the Transportation Research Board (TRB), a division of the National Academies, under a memorandum of understanding with the Federal Highway Administration (FHWA) and the American Association of State Highway and Transportation Officials.

SHRP2 is supporting research to evaluate the underlying causes of highway crashes and congestion and to address the role of driving performance and behavior in traffic safety. Most of the $67 million allocated for safety research is being spent on the Naturalistic Driving Study. According to TRB, this is the largest study of driving behavior ever conducted

The study is also expected to produce data that show how drivers react to pedestrians and behave in work zones like this one.

TRB

This head unit, which is attached near the rear-view mirror of a participant's vehicle, contains four cameras that record four different fields of view. The unit also contains accelerometers and a passive alcohol sensor that measures the concentration of alcohol vapor in the cabin air. The sensor indicates the possibility of an impaired occupant. Alcohol in after-shave, however, also will be sensed. The sensor does not indicate blood alcohol concentration.

TRB

These four fields of view from the cameras in one of the participant's vehicles are combined into a single frame and compressed for efficient storage.

in terms of participants and data that will be generated. About 3,100 volunteer drivers at data collection sites in six States are participating. The drivers are allowing researchers to install cameras and sensors in their vehicles to deliver data captured in real time, making it available to scientists and engineers.

Data collection began in late 2010 and will end in November 2013. The data collected will exceed 4 petabytes, or twice the size of all the information contained in every academic research library in the United States in 1997. The study team expects the data to remain useful to transportation safety researchers and others for up to 30 years, providing an abundance of information regarding driving behavior, lane departures, and intersection activity.

"A long list of research topics has been identified, and interested researchers are eager to use these data to improve highway safety," says Robert Skinner, TRB's executive director. "They believe we can learn things we didn't know before that will enable us to develop countermeasures, design vehicles better, and design more forgiving roadways. The challenge is to have the data available to them in formats that are understandable and usable."

In collaboration with Battelle Memorial Institute and the University of Michigan Transportation Research Institute, Virginia Tech Transportation Institute (VTTI) designed the field study and defined requirements for a data acquisition system that collects kinematics (information about a vehicle's motion, including velocity and acceleration data) and video of naturalistic (or real-world) driving behavior. Each of the 1,950 vehicles used for the study is equipped with this system, which will yield approximately 3,900 vehicle-years of data over 2 years. The system includes four video cameras, velocity and acceleration sensors, GPS, forward radar, an incident button, a light sensor, and a passive alcohol sensor. Machine vision tools to track lane fidelity and an eyes-forward monitor also are part of the system.

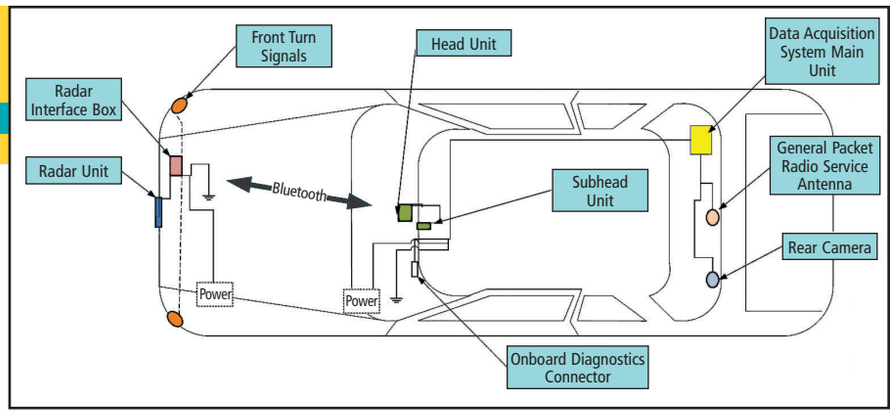
The VTTI researchers are storing and managing a databank that contains data on demographics, vehicle inventories, driver assessments, and crash investigations. To capture a range of geographic, road type and usage, State law, and weather factors, researchers are collecting data at locations in six States: Florida, Indiana, New York, North Carolina, Pennsylvania, and Washington. As the technical contractor for the study, VTTI is providing coordination and quality control, as well as oversight of the contractors that are gathering and storing data for future analysis projects.

"Data quality assurance is a big part of this," explains VTTI research scientist Jonathan Antin. "We verify that the vehicles are collecting data and doing what they're expected to do. Through an automated health check, the data acquisition system self-assesses certain aspects of its performance and functioning. It transmits that information by cellular network back to us, and we begin to interpret it."

Participants and Trips

Age and gender were key criteria in recruiting participants in order to assemble a robust mix of young, middle-age, and senior drivers from both sexes. Volunteers took a series

Shown is a schematic view of the data acquisition system.



TRB

of assessments of driving-related skills and attributes, such as visual perception, visual-cognitive ability, psychomotor ability, physical ability, health and medication status, psychological factors, driving knowledge, and driver history. At enrollment, each volunteer in the study signed an informed consent. The institutional review boards of the National Academy of Sciences and other contracting agencies approved all activities required of the subjects.

Obtaining data about drivers, vehicles, and roads is necessary to answer questions about what influences the risk of being in a collision. Researchers need to see what drivers see and where they are looking. Key data collected include speed, distance from the car ahead, acceleration, steering and pedal action, seatbelt use, geographic location, and vehicle characteristics and performance. Onboard computers encrypt and store data obtained from the data acquisition system, then upload the data to a central repository.

Much of the study data consist of logged trips and road data. A trip begins just after a vehicle's ignition is turned on and ends when it's turned off. To enable data users to identify trips of interest, the researchers are organizing trips into summary files, which contain basic identifiers such as driver age and gender; vehicle make, model, and model year; maximum speed; highest deceleration; and time driving. As of February 2013, the study database included records on more than 3.4 million trips and about 250 crashes.

The Roadway Information Database

In addition to the trip database, the study includes a road database. Determining the relationship of roadway characteristics to crash risk and driver behavior requires detailed data about road grade, curvature, cross slope, lane and shoulder width, posted speed limits, medians, rumble strips, intersections, and other characteristics. Iowa State University's Center for Transportation Research and Education (CTRE) is collecting these types of data.

Researchers at CTRE are creating a spatial database of roadway characteristics and features, as well as other supporting data—including crash histories, traffic volumes, weather, work zones, and safety campaigns and laws—that can be used to describe the context in which the participants drive. The CTRE researchers are populating the roadway information database with existing data acquired from State and local agencies and public and private sources.

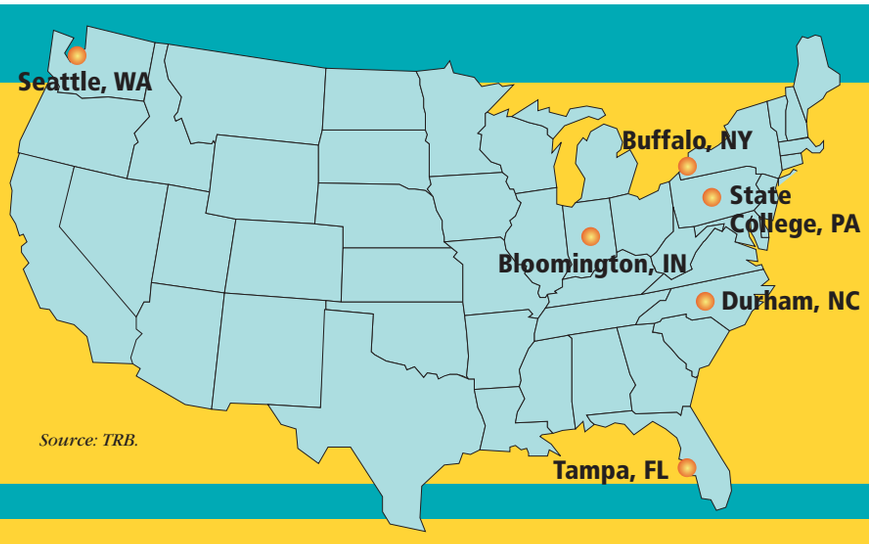
At the same time, Fugro Roadware, a vendor of data collection solutions for roadway infrastructure, is collecting additional data on roads that the participants drive frequently. In total, the vendor will collect data on more than 2,000 centerline miles (3,219 kilometers) in each of the six study sites, totaling 12,500 centerline miles (20,117 kilometers), or 25,000 miles (40,234 kilometers) driven (the researchers are collecting the data in both directions).

SHRP2 will link the roadway data collected by CTRE to the naturalistic driving database to support analysis. Key aspects of the project include data integration, quality control and assurance, storage,

Six Sites

The driving study has been operational at all six sites since spring 2011. From west to east, the sites are located in Seattle, WA; Bloomington, IN; Tampa, FL; Durham, NC; Buffalo, NY; and State College, PA.

The contractors selected to establish and operate the field data collection sites are responsible for installing equipment and conducting driver assessments, collecting and transmitting data, addressing problems, investigating crashes, and preparing periodic reports documenting the field study activities.



Source: TRB.

Analyzing the Data

The Naturalistic Driving Study is expected to produce data that researchers can use for at least 20 years. The following projects involve analyzing early data from the study.

Relationship between driver behavior and safety on curves: conducted by CTRE. Crash rates are 1.5 to 3 times higher on horizontal curves than on straight road sections. DOTs use various countermeasures to improve safety on curves, including installing signs and rumble strips to warn drivers about curves, delineating curves through chevrons and pavement markings, and minimizing the impact of road departures through paved shoulders and guardrails. But little information is available on how drivers respond to such roadway measures and why these roadway measures work or do not work. This CTRE study will use trip and roadway data from the Naturalistic Driving Study to examine how motorists interact with the roadway environment and what cues and measures are the most effective in influencing driver behavior. The study is expected to help highway departments implement more cost-effective measures to prevent or mitigate road-departure crashes on curves.

Driver inattention and crash risk: conducted by the SAFER Vehicle and Traffic Safety Centre at Chalmers University, Göteborg, Sweden. In 2009 distraction was involved in crashes causing 5,474 deaths and leading to 448,000 traffic injuries across the United States. Currently, measuring driver inattention and estimating the effect of inattention on crash risk remains a challenge. The SAFER study will use the Naturalistic Driving Study and roadway data to develop a measure of driver inattention based on observable driver actions, such as eye glances away from the road, and will estimate how driver inattention and the roadway environment combine to influence crash risk. The results will help establish guidelines for how long a driver can safely look away from the road and will help design invehicle technologies to measure driver inattention and warn inattentive drivers.

Evaluation of offset left-turn lanes: conducted by MRI Global, Kansas City, MO. Many intersections provide designated left-turn lanes where vehicles can wait apart from through-traffic lanes until it is safe to turn. However, vehicles waiting in standard left-turn lanes (in which the roadway's centerline continues straight through the intersection) may have their view of oncoming through-traffic obstructed by vehicles in the opposing left-turn lane. One way to address this issue is to offset the left-turn lanes to the left, so vehicles waiting to turn are positioned to the left of the centerline of the opposite side of the intersection. Many highway designers have accepted these offset left-turn lanes in principle, but evidence of their effects on driver behavior or crashes remains inconclusive. The MRI Global study will use the Naturalistic Driving Study's roadway data to analyze how driver left-turn behavior, such as gap acceptance, is influenced by intersection and traffic characteristics and especially by offset left-turn lanes. This will help DOT officials design intersections that balance construction and maintenance costs against crash risk.

retrieval, analysis, maintenance, reporting, and representation.

Data Processing and Analysis Phase

"Data collection is about half done, and about one-fourth of the data has been uploaded from the vehicles to the database at VTTI," says SHRP2 safety chief program officer Ken Campbell. "Now our focus is shifting to data processing and data access. Issues [to be addressed] are the size of the database, over 4 petabytes, and maintaining the privacy assurances made to participants while providing access to data users."

One of the benefits of the Naturalistic Driving Study will be the precrash, crash, and exposure (or baseline) data that it produces. Exposure data is obtained from normal, uneventful driving.

When the participants' vehicles are running, the data acquisition system records continuously. Thus, the researchers will have access to crash and near-crash data, as well as baseline data representing samples of driving when no safety-related event occurred. A primary goal of the analysis is to determine the extent to which roadway design, traffic conditions, intersections, and advanced vehicle technology influence driving behavior and the risks inherent in these factors.

"Part of what we're trying to do is develop confidence levels in the various data types we collect," says Omar Smadi, director of CTRE's Roadway Infrastructure Management & Operations Systems program. "We are working with the State DOTs [departments of transportation] in each area to get [their data] on the roadway and transportation infrastructure, and we're working with VTTI to get GPS traces from participants to develop data collection maps." In this context, GPS traces are the routes frequently driven by the study participants.

Professor Shinar adds: "In highway safety, we do not have a single, accepted theory of driver behavior. Thanks to the *Tri-Level Study*, we know that most crashes happen to normal people involved in normal activities but overwhelmed with a particular situation at the time of the crash, or just before it happens."

For each crash, the records will contain a summary of what happened in the seconds before and after the event. The data is expected to show what the driver was doing that might have caused or contributed to the crash. After certain crashes (for example, those in which air bags deployed), researchers will conduct onsite crash investigations to gather additional data.

Road type, geometry, shoulders, safety infrastructure, signs, and pavement markings will be important factors in the study analysis. Researchers also will consider environmental variables such as traffic, lighting, and weather conditions.

"This information will support the development of new and improved countermeasures with greater effectiveness," says Shinar.

Long-Term Stewardship

The SHRP2 safety team will analyze the data to quantify the contribution of relevant driving, roadway, vehicle, and environmental factors,

TRB

The invehicle data acquisition system unit, shown here, gathers and stores data from forward radar, four video cameras, accelerometers, vehicle network information, a GPS, and onboard computer vision algorithms.

and will assess the implications of the findings in terms of potential countermeasures. Knowledge gained from these analyses, as well as those performed by other researchers, is expected to support public policy, rulemaking, infrastructure improvements, vehicle design, and other activities targeting crash reductions on the Nation's roadways. Effective management of the data is essential for establishing systems and products to improve driving safety.

"We need to protect the human subjects in the research and ensure confidentiality, and at the same time we want researchers who have good reason to use the data to have a way of getting it," says SHRP2 Director Ann Brach. "One of the decisions we made within TRB, SHRP2, and the SHRP2 Oversight Committee was to make sure we started funding the use of the data before we finished collecting it. This will enable us to demonstrate that it can be used and have some lessons learned so we can make improvements."

SHRP2 is scheduled to end in March 2015, not quite 2 years after completion of the data collection. To develop options for the long-term stewardship and ownership of the data, FHWA is sponsoring a study with the John A. Volpe National Transportation Systems Center, a component of the USDOT's Research and Innovative Technology Administration. The goals of the study are to protect the privacy of participants, make the data widely available for research purposes, ensure the sustainability of the data system for at least 20 years, and minimize the costs associated with supporting and maintaining a secure data system.

"Ownership of the data is the dominant issue underlying practically everything we're discussing regarding long-term stewardship," says Monique Evans, director of FHWA's Office of Safety Research and Development at the Turner-Fairbank Highway Research Center. "Federal Government ownership brings with it major institutional requirements and standards that have to be met, covering privacy, security, record keeping, and other considerations. These requirements can be expensive and cumbersome, but are considered by many to be best practices.

"Currently TRB owns the data, and the Government has access rights to it. Our ultimate goal is to answer critical safety questions by ensuring that the research community has convenient and affordable access to the data while protecting the privacy of the study participants," says Evans.

Privacy and Sharing

One of the major challenges of having such rich and comprehensive data will be figuring out how to make it publicly available while also protecting the privacy and identities of those who volunteered. Privacy protections were promised to

TRB

This forward radar unit, mounted next to the license plate, is among the data-gathering devices installed in or on participants' vehicles.

Speed, lane changing, and following distance are important factors related to safety on highways like this one. In 2008, speed was a contributing factor in 31 percent of all fatal crashes, and 11,674 lives were lost in crashes related to excess speed.

participants, but their data will continue to be analyzed for decades after the study ends. Secure data facilities, data-sharing agreements, and approvals by institutional review boards will be used where appropriate.

Currently, all of the data from the study reside at VTTI. "For right now, the protocol for researchers who want to access the data requires a contract and funds to support data preparation, institutional review board approval, a data-sharing agreement, and SHRP2 approval for non-SHRP2 projects," explains VTTI research scientist Suzie Lee. "Identifying video, which is video where participants are recognizable, and full GPS traces have to be viewed at VTTI's secure data enclave, but nonidentifying data can be shipped out without further review."

Data-sharing agreements are contracts between data stewards and research teams, specifying that data are to be shared and used in accordance with privacy promises made to the participants. Currently a 3- to 4-page document, the agreement requires researchers to present a scope of analysis, specify the dataset requested, secure institutional review board approval or proof of exemption for nonidentifying data, undergo human subjects training, and establish a timeframe for data retention.

"The human subjects training is typically an online course that can take between 45 to 90 minutes," explains Lee. "It basically grounds you in the principles of human subjects' protection and makes you aware of why we are protecting the privacy of the participants."

All protections required for the rights and safety of participants in human subject research are in place, and the institutional review boards of the National Academy of Sciences and other contracting agencies have approved each step of the study design.

Using the Data in Projects

FHWA set aside $10 million out of SHRP2 funds for implementing projects to improve safety. As a way of targeting high-priority areas for safety research, FHWA developed roadmaps keyed to places where a large number of traffic fatalities are occurring. "We're in the process of identifying projects from these roadmaps as well as new projects that might be higher risk or more advanced, or call for long-term studies in high-priority areas that could be addressed using SHRP2 safety data," explains FHWA's Evans.

Also, FHWA is pursuing projects in its Exploratory Advanced Research (EAR) Program to identify and develop tools to support the efficient use of massive amounts of data. One project is a 2-year study on automated extraction of video data to facilitate the analysis of large quantities of transportation research data and video.

Additional projects might result from a workshop on video analytics that was held at Turner-Fairbank on October 10–11, 2012. At the workshop, FHWA brought together professionals from academia, the private sector, and government to identify research needs and interests in advancing automation techniques that facilitate the efficient extraction of features in videos on driving behavior. "What you're looking for depends on what you're trying to study," points out FHWA EAR Program Director David Kuehn. "So the questions are: What do you need to extract and what are the key behavioral or inattention problems you're looking for? What are the differences in the algorithms you may need to identify?"

The EAR Program is interested in advancing technology for sensors, video, and signal processing that could result in transformative changes in the way researchers investigate human behavior and human-machine interaction. Kuehn expects the study on automated extraction of video data to demonstrate the effectiveness of advanced machine vision techniques applied to large and diverse datasets and enable the development of a comprehensive library of data processes and analysis tools. Information generated from the workshop could be useful in considering methods to save time by speeding up the process of examining particular data.

A National Discussion

The Naturalistic Driving Study marks the beginning of a national discussion that is likely to influence implementation of new standards and advanced technologies. Although

it is too early to know the impact that the study's data will have on safety, wireless communications for vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) applications have shown strong potential. For example, V2V systems that enable cars to talk to each other can warn drivers of dangerous road conditions, and intelligent intersections equipped with V2I technologies can advise drivers to slow down to avoid running a red light. Researchers are advancing tests of these applications under real-world, multimodal driving conditions to determine their effectiveness, safety, and ability to help reduce crashes. Might future V2V and V2I systems informed from the findings of the Naturalistic Driving Study serve to deter excessive speed, inattention, and other potentially dangerous driving behavior?

Future efforts and discussions aimed at ensuring that the study's data are put to good use will continue to focus on instituting protocols and creating living documents that emphasize privacy protection and research intent. Questions of how to house and maintain the enormous database also will continue to be addressed. "The data will be housed in at least one secure facility—Virginia Tech's—and possibly others," says SHRP2 Director Brach. In the future, other facilities might hold and protect the data as well.

FHWA has initiated a feasibility study to establish a support enclave for safety data analysis at Turner-Fairbank. According to FHWA Director of Safety Research Evans, the enclave would serve to advance knowledge about the data and range of usage. "It would provide assistance to State DOTs regarding use of the data and opportunities for researchers to get hands-on training and experience with the data through internships, sabbaticals, and other avenues," she says.

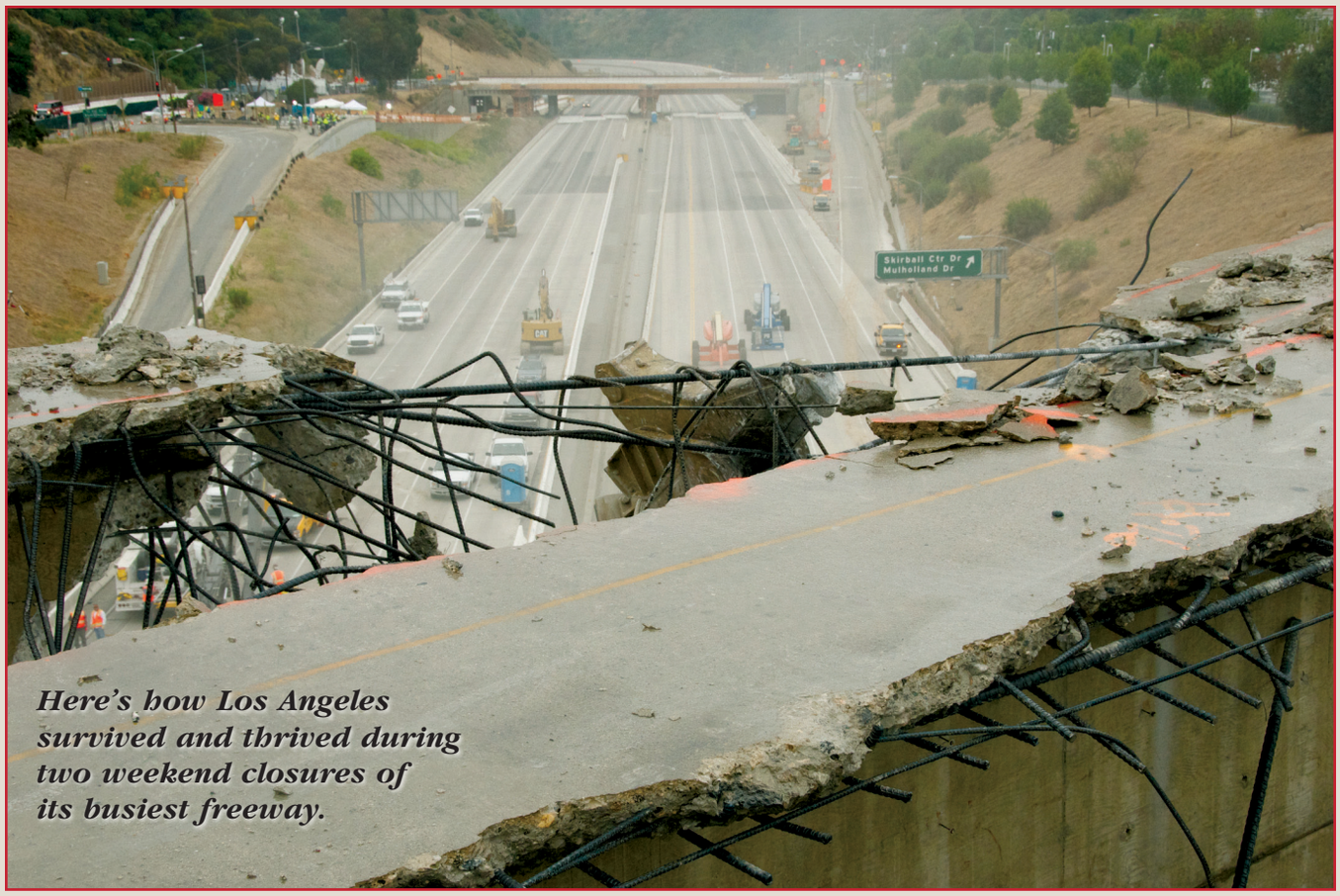
Researchers involved with data collection and analysis are discussing the feasibility of producing some additional categories of data files, featuring near-crash events, exposure samples, a small sample of trips, and specialized trip characteristics. Near-crash files would be assembled in a similar manner as crash files. For example, the files could contain events with extreme braking or steering maneuvers. Definitions for near-crashes are under development.

"We would like to get a better understanding of the relationship between crashes and near-crashes and critical maneuvers," says NHTSA's Compton. "These are typically the things that are not well understood, and not easily understood through post-crash investigations, where exposure and precrash driving behavior would make a tremendous difference in understanding how driver behavior contributes to crashes. I think this is one of the first things we'll tackle with these data."

Mark Fitzgerald is a senior writer at Woodward Communications and teaches writing at the University of Maryland, College Park. Before joining Woodward, he was the editor of several trade magazines and worked at the American Society of Civil Engineers. He has a B.A. in English from Franklin & Marshall College and an M.F.A. in creative writing from George Mason University.

For more information about the Naturalistic Driving Study, see www.shrp2nds.us. To read more about the SHRP2 safety research program, visit www.trb.org/SHRP2/safety or contact Mark Fitzgerald at 202-493-3995 or mark.fitzgerald.ctr@dot.gov.

Researchers hope to gain a better understanding of driver distraction through data obtained from the Naturalistic Driving Study. This photo shows a driver (who is unidentifiable and not a study participant) using a cell phone while operating a motor vehicle.



Here's how Los Angeles survived and thrived during two weekend closures of its busiest freeway.

The Road Not Taken

by Judy Gish

To build a high-occupancy vehicle (HOV) lane, the California Department of Transportation (Caltrans) and the Los Angeles County Metropolitan Transportation Authority (Metro) needed to demolish a bridge. Not just any bridge, but the iconic Mulholland Bridge. And not just any HOV lane, but the last segment of the HOV system on I–405 from west Los Angeles to the San Fernando Valley, which will enable carpoolers to travel in both directions from northern Los Angeles County all the way to Orange County.

Demolish a bridge? That's no big deal for Caltrans. The trouble was that demolition would require closing a section of one of the busiest freeways in the United States.

As far as local officials and the media were concerned, the planned 53-hour closure would unleash a snarling traffic monster that would bring the city to its knees. That is, unless the vast majority of the 500,000 vehicles that normally travel on I–405 through the Sepulveda Pass on a mid-July weekend in 2011 could somehow stay parked at home. In Los Angeles, where the freeways never sleep? Who were they trying to kid?

(Above) To demolish Mulholland Bridge (shown in the foreground) in Los Angeles County, Caltrans closed this segment of I–405, one of the State's busiest freeways. Media outlets set up camp (upper left) nearby to report on the project, dubbed Carmageddon. *Photo: Caltrans.*

Reaching Out to the Public

The key to avoiding chaos was a public outreach campaign to ensure that every man, woman, and child in Los Angeles County, the State of California, and practically the entire western United States would know about the closure. Putting the campaign together involved an enormous effort led by Metro, Caltrans' partner in this project.

Caltrans

Crews assemble on top of and underneath the south side of Mulholland Bridge over I–405 as demolition is about to begin during Carmageddon I in July 2011.

this is the most gratifying experience of this kind that I have had," said then Governor Edmund G. Brown, Sr., in a message read at the ceremony.

Fifty years ago, government officials had envisioned as many as 100,000 vehicles traveling over the route once the 40-mile (64-kilometer) stretch of I–405 was complete from San Fernando to Long Beach. What the agency did not anticipate was that five decades later the Sepulveda Pass section of I–405 would carry traffic levels five times that number.

Because it was unthinkable that Californians would forgo their normal trips to and fro, the plan was to warn motorists to expect *massive* delays—easily 3 hours or more. Plan ahead; leave early; and, above all, avoid I–405 anywhere near the 10-mile (16-kilometer) northbound closure and the 4-mile (6.4-kilometer) southbound closure.

This was the word conveyed to the public on Caltrans' changeable message signs all the way from the State's Oregon border down to Mexico. Specifically, the message signs in southern California read, "405 WILL CLOSE RTE 10 TO 101 JULY 16–17 EXPECT BIG DELAY." Those posted elsewhere read, "LOS ANGELES FWYS EXPECT BIG DELAY JULY 16–17." A month ahead of the closure, a total of 64 signs began displaying the message on Los Angeles County freeways. As the date approached, more than 30 additional signs were placed at freeway locations and an additional 40 to 50 on surface streets.

The fact that long after the project's completion people are still discussing "Carmageddon," as the closure came to be known, demonstrates the success of the public awareness campaign. But first, a closer look at the project itself and its background.

An Introduction to I–405

When State and local officials gathered on December 21, 1962, to dedicate the newest addition to I–405, an eight-lane, 5.7-mile (9.2-kilometer) section between west Los Angeles and the San Fernando Valley, they were thrilled to provide a quick alternative to the steep turns of four-lane Sepulveda Boulevard, an adjacent road winding over the Santa Monica Mountains.

"With the possible exception of the dedication of the downtown Los Angeles freeway loop last March,

Shown here is the I–405 project area between the Ventura Freeway (State Route 101) and Santa Monica Freeway (I–10). *Source: Caltrans.*

Caltrans

Equipment operators chipped away at the old bridge from above and below, adhering to a carefully timed demolition plan to ensure that the old structure would be removed and the area cleared in time to reopen the highway for the Monday morning rush hour.

I–405 is the only freeway directly connecting the coastal cities of Los Angeles with the San Fernando Valley, hence its popularity. Lacking available space for building additional freeways, Caltrans' strategy for reducing congestion is to maximize the efficiency of the existing freeway, in part by building HOV lanes. For the past decade, the agency has been adding carpool lanes along the route. All that remained to complete the system was the 10-mile (16-kilometer) stretch northbound from the Santa Monica Freeway to the Ventura Freeway.

Remedying Current Traffic Woes

According to Caltrans' *2011 HOV Annual Report*, which contains the latest figures available, Los Angeles County has 514 lane-miles (827 kilometers) of HOV facilities, or 36 percent of the nearly 1,425 lane-miles (2,293 kilometers) of HOV infrastructure in California. On average, each HOV facility in Los Angeles County carries 1,400 vehicles, or 3,400 persons, per hour during peak periods. In all, the HOV facilities in the county carry approximately 326,000 vehicles, or 763,000 persons, daily.

On average, HOV lanes carry twice as many persons as regular-use lanes. That translates to accommodating 33 percent of freeway users in just 20 percent of the space, while an adjacent single mixed-flow lane carries 17 percent of the entire freeway's users in the same 20 percent of space.

After years of planning, work on the final segment of the HOV lane started in summer 2009. Caltrans and Metro awarded a design-build contract for the carpool lane—the first such contract let for a freeway project in this part of California. The main advantage to the design-build method is speed of construction, along with greater flexibility to respond to conditions as they arise.

Considering that I–405 through the Sepulveda Pass needed immediate congestion relief, Caltrans officials deemed the project an ideal candidate for design-build.

State legislation (SB 1026) passed in 2006 required that the regional transportation agency be in charge of design-build projects. As a result, Metro is responsible for administering the I–405 contract, and Caltrans has oversight. The State picked up 60 percent of the $1.3 billion price tag, while the Federal Government covered 30 percent, including $189 million in funds available through the American Recovery and Reinvestment Act. Local funds paid for the rest.

In addition to constructing the 10-mile (16-kilometer) HOV lane, the project is improving the supporting infrastructure, including ramps, bridges, and sound walls. The project also removes and replaces 3 bridges, realigns 27 on- and off-ramps, widens 13 existing underpasses and structures, and constructs approximately 18 miles (29 kilometers) of retaining wall.

Describing widening and improving one of the Nation's most congested highways, while keeping it functional, Project Manager Mike Barbour of Metro said in a live Web chat, "This project is as challenging

Caltrans

Debris rains down from the old bridge as crews continue the demolition work.

as performing heart surgery on a patient while she runs a marathon."

The three bridges that needed to be replaced were the Sunset, Skirball, and Mulholland. The project contractor could demolish and reconstruct both the Sunset and Skirball bridges with minimal disruptions to traffic by closing freeway lanes for a few overnight hours over the course of 6 and 7 nights, respectively.

The Mulholland Bridge was another story. Because this bridge had no center bent (a rigid frame commonly made from reinforced concrete or steel that supports a vertical load) and a 60- to 70-foot (18- to 21-meter) vertical clearance, it required significantly more time to demolish. To reduce the impact on local traffic flow, bridge demolition and construction would take place in two phases: the south side first, followed by roughly a year of reconstruction, and then the north side. After the south side was demolished, the north side would be used to carry two-way traffic while the new south side bridge was constructed. Then, the north side would be demolished and the new bridge installed, as traffic flowed in two ways on the south side bridge. Transportation officials and the contractor decided that one painful 53-hour closure was the most efficient way to handle the demolition phases.

Planning for the Closure

Although project officials had been planning for the closure for some time, the exact date—the weekend of July 16–17, 2011—was finalized just 10 weeks before the closure was to occur. In addition to the construction schedule, planners took into account other factors in picking that date, including the fact that schools would not be in session and that, in general, freeway traffic is slightly reduced during the summer months.

With Metro responsible for developing and implementing the outreach plan and Caltrans in charge of alerting motorists throughout the State, information officers from both agencies began hyperventilating as the closure date approached. The plan included several elements: a dedicated Web site and hotline; social media consisting of Twitter, Facebook, a blog, and Web chats; a speakers' bureau; and weekly email blasts to 6,000 contacts.

As outreach efforts continued, other city and county agencies became involved, including the Los Angeles International Airport, which made sure that its customers from around the globe were aware of the closure.

On the media outreach side, the first of four press events occurred on June 6, 2011, along with distribution of a press release to local, regional, and national media. The first press conference was when reporters embraced the term "Carmageddon," which Los Angeles County Supervisor Zev Yaroslavsky mentioned in his remarks.

Although paid advertising was part of the outreach plan, it was hardly needed from that point forward. Reporters seized upon the word, the closure, the project—the entire catastrophe-in-the-making idea—and began to cover the impending doomsday 24/7.

Before it would be over, hundreds of articles would be written in publications as far away as Europe and stories broadcast on television and radio stations from Los Angeles to New York.

Municipal authorities decided to treat the closure as an emergency response effort, putting the Los Angeles Police Department and Los Angeles Fire Department in charge. The city set up a joint information center at the police emergency management center in downtown Los Angeles to operate during the closure. There, a traffic management team consisting of Caltrans, the California Highway Patrol, Metro, emergency response officials, and the Los Angeles Department of Transportation oversaw the operation from an upstairs room. At the same time, personnel from Caltrans and the California Highway Patrol observed the situation via cameras at the Los Angeles County Regional Transportation Management Center near Pasadena.

Downstairs, about 20 public information officers from local, State, and Federal agencies responded to calls from the public and media, and sent out frequent updates on Twitter, Facebook, and Nixle (a notification service for law enforcement and government agencies). At the same time, Caltrans kept a real-time watch not only on I–405 but on all of the freeways in Los Angeles and Ventura Counties from the agency's transportation management center.

The Arrival of Carmageddon

And so it began. Ramps on I–405 began closing at 7 p.m., July 15, 2011, continuing through midnight as freeway lanes and connectors

Caltrans

This aerial shot was taken during the early stages of demolition. What looks like traffic is actually the workers' parked vehicles.

Caltrans

By Saturday afternoon of Carmageddon I's weekend closure, only three pillars remained standing.

closed one by one. Media outlets had set up camp at a designated bridge site and were there reporting throughout the weekend.

As demolition proceeded, smoothly, it soon became apparent that the monster that would consume the city seemed to be *asleep*. In fact, Los Angeles County freeway traffic delays dropped 44 percent from the previous weekend, and vehicle-miles traveled dropped 12 percent. Just south of the closure, northbound I–405 traffic on Saturday, July 16, dropped 61 percent from the previous week and southbound I–405 traffic just north of the closure dropped 73 percent.

Los Angeles traffic had been scared straight! Motorists stayed off the freeways, the canyons, the streets, and all of the little shortcuts they would normally take. They rode bikes, walked to local attractions, or entertained at home. Some enterprising sorts even sold T-shirts and other memorabilia, while many businesses offered closure-related specials. JetBlue Airways invited Los Angelinos looking to get across town during the closure to take advantage of $4 flights each way from Burbank to Long Beach. In response, some bloggers challenged a group of bicyclists to a plane-versus-bike race from Burbank to Long Beach. The cyclists, who made the journey in about 1.5 hours, won the race, despite the short half-hour flight time, once the flight check-in and security processes were factored in.

Unfettered by traffic and encountering no unexpected issues, the contractor completed demolition and reopened the freeway to motorists at noon on Sunday, about 17 hours ahead of the estimated timetable. Instead of Carmageddon, some started calling it "Carmaheaven" and suggested making the closure an annual event.

Carmageddon II

Of course, Los Angelinos would have the opportunity to be carefree and go car-free again the following year, when Carmageddon II, as it was affectionately called, took place over the weekend of September 29–30, 2012.

As with the first closure, project staff knew the closure was coming, but again—due to the flexibility and therefore slight unpredictability of the schedule in the design-build process—were not sure exactly when. The timeline between the confirmation date and the closure turned out to be roughly the same as in the previous year. And, as before, public and media relations folks jumped into action.

The message this time was "eat, shop, and play locally," initially delivered via press release on July 19, 2012, and followed by an interagency press conference 2 weeks later. Los Angeles Mayor Antonio Villaraigosa called Carmageddon I "truly one of L.A.'s finest moments" and exhorted the public not to become complacent based on the previous year's low vehicle turnout. "We are again calling on the public to do its civic duty," he said.

"I have every confidence [drivers] will rise to the occasion again," said Los Angeles County Supervisor Yaroslavsky. "Let's make this another Carmageddon-Schmarmegeddon experience for us all."

Metro's campaign emphasized alternative transportation options, offering special Carmageddon discounts of up to 50 percent at

Caltrans

A Caltrans public information officer exults in a rare opportunity to stand on I–405 while it is free of traffic.

Caltrans

Photographed during Carmageddon II, the north side of the bridge is nearly demolished, with the newly constructed south side visible to its left.

participating retailers to bus and transit riders. Numerous local businesses joined in with their own discounts linked to the use of public transportation over the weekend. Cooperation was particularly important during Carmageddon II because the work was more involved and early completion was unlikely.

Shortly before the closure, Caltrans debuted QuickMap, an interactive online tool and application that provides access to nearly 1,000 freeway cameras throughout the State and more than 700 electronic message signs. Site visitors could monitor traffic congestion, California Highway Patrol responses to incidents, travel-time information, road closures, and Amber Alerts. The application offered area motorists one more way to navigate around the closure.

The closure was implemented exactly as it had been before, with agencies again joining the police and fire unified command at the Los Angeles emergency operations center, establishing a 24-hour watch at the transportation management center, and deploying 30 additional electronic message signs. In addition to the demolition work, the closure presented a unique opportunity to perform 7 weeks' worth of maintenance work elsewhere on the roadway segment in 48 hours.

The work consisted of sweeping, clearing storm drains, inspecting bridges, sealing pavement cracks, restriping, replacing freeway signs, installing new raised pavement markers, and removing graffiti.

Carmageddon II went on without incident. Travel lanes reopened by late Sunday evening, around 7 hours ahead of schedule, providing more than enough time to prepare for the morning commute, which saw a return to traffic as usual. Los Angeles had done very well on foot, bicycle, bus, and train, roughly cutting in half the number of vehicles on the freeway.

The Power of Cooperation

Much like the reputed bliss of the 1984 Summer Olympics, when the sometimes unruly city was at its civilized best and its citizens united to provide visitors with easy access to all Los Angeles has to offer, Carmageddons I and II showcased the power of cooperation and partnership.

Caltrans and Metro partnered to build a much-needed carpool lane, law enforcement and emergency service agencies partnered with State and local transportation agencies to keep the city safe and functional during the unprecedented event, and members of the public embraced their responsibilities and stayed off the roads. What could have been a nightmare became a dream of life without traffic.

Carmageddon III, anyone?

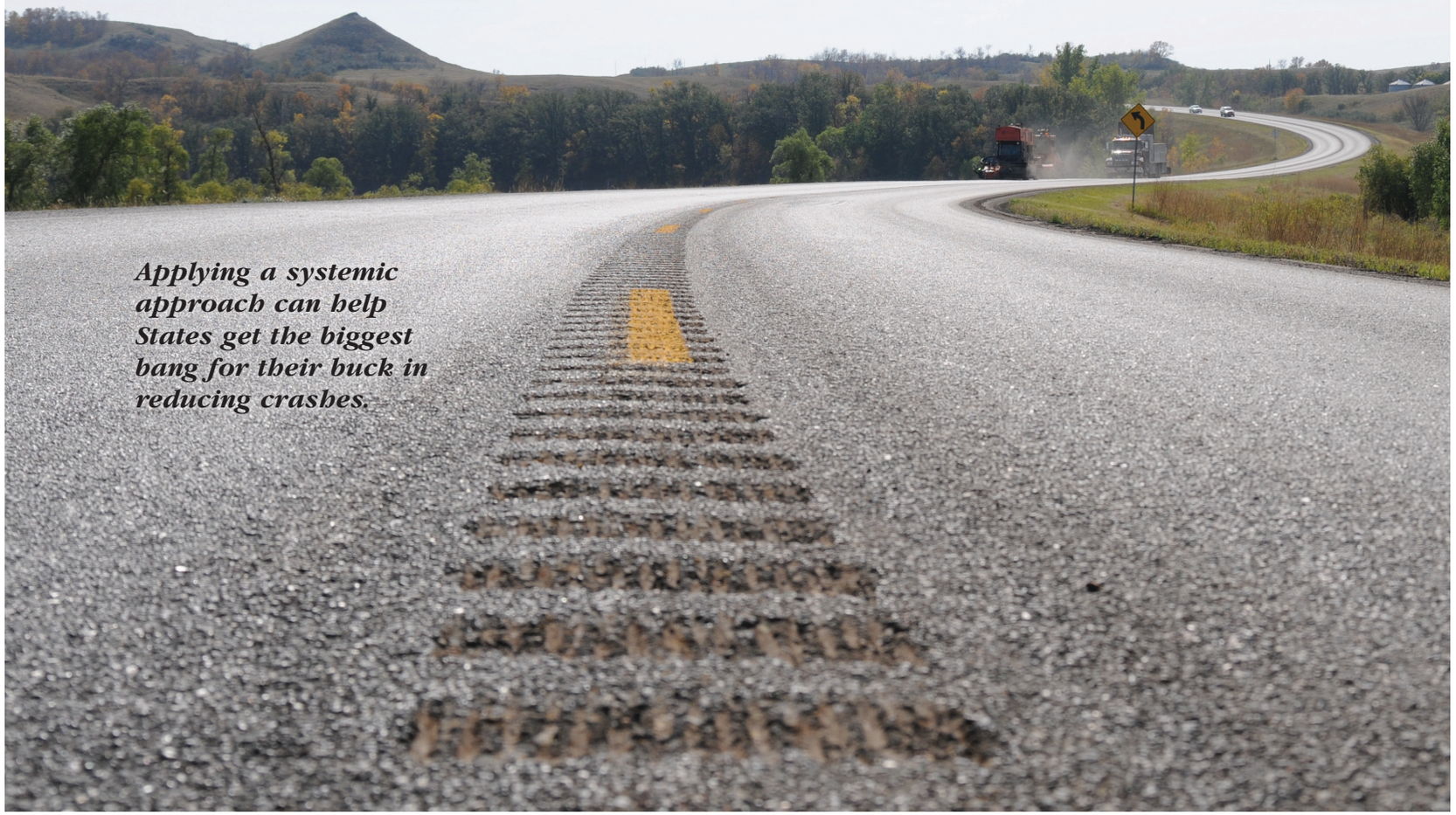
Judy Gish is a public information officer for Caltrans in Los Angeles. Her background includes writing for several publications on a variety of transportation issues. She experienced Carmageddon firsthand and frequently finds herself on I–405 wondering if she will ever get home.

For more information, visit www.metro.net/projects/I-405/mulholland-dr-bridge-demolition-reconstruction or contact Judy Gish at 213-897-3487 or judy.gish@dot.ca.gov.

Caltrans

Caltrans vehicles lead the way as the freeway reopens to traffic on September 30, 2012, after Carmageddon II.

Using Risk to Drive Safety Investments



Applying a systemic approach can help States get the biggest bang for their buck in reducing crashes.

(Above) During construction of this rural two-lane road, the North Dakota Department of Transportation installed centerline rumble strips, a typical systemic safety improvement. *Photo: North Dakota Department of Transportation.*

The traditional approach to planning safety improvements on roads involves identifying locations with a higher than expected number of crashes and then making needed upgrades at those locations. Over the years, this "site analysis" approach yielded a reduction in the number of locations across the country where multiple fatal crashes have occurred. In fact, the annual number of highway fatalities has dropped from nearly 42,000 in 1994 to less than 33,000 in 2010. At least part of this reduction is the result of the emphasis on safety made at the Federal, State, and local levels.

Mounting evidence indicates that fatal and other life-threatening crashes often are distributed widely across State and local highway systems,

by Howard Preston, Richard Storm, Karen Scurry, and Elizabeth Wemple

in both urban and rural environments, with few individual locations experiencing a high number or sustained occurrence of severe crashes. Consequently, some departments of transportation (DOTs) have adopted a new approach to planning safety improvements on their networks, initiating policies and programs to advance the implementation of low-cost safety countermeasures widely across a roadway network. The widespread implementation of low-cost countermeasures—that is, deployed everywhere—is known as a "*systematic*" approach. In an ideal world, where staff resources and budgets were sufficiently available, the systematic approach might be the preferred solution.

However, at a time when DOTs cannot afford to apply treatments equally at all locations, planners are looking instead to set priorities among potential locations for safety improvements. In this case, planners are adopting a "*systemic*" approach to implementation. Systemic implementation involves the identification of the locations across the network that *have the greatest risk* for severe crashes, and then prioritizing those for investments in safety improvements.

The systemic approach involves use of analytical techniques to identify sites for potential safety improvements based on the presence of high-risk roadway features. Examples of possible roadway features that influence crash risk include the number of lanes, median width, and average annual daily traffic. This approach suggests projects for safety investment that typically might not be identified through traditional site analyses with the priority focus on locations where a high number of severe crashes has occurred. The systemic approach complements traditional site analyses and provides a comprehensive and proactive approach to planning safety improvements to help prevent the most severe crashes on the Nation's roadways, which are typically distributed widely across the network. The systemic and site analysis approaches feature the same basic planning steps included in the Highway Safety Improvement Program (HSIP) and most common safety management processes.

The Moving Ahead for Progress in the 21st Century Act (MAP-21) emphasizes reducing fatal and serious injury crashes on all public roads. The legislation acknowledges that a State's HSIP should identify projects to improve safety not only on the basis of crash history, but also crash potential. Further, MAP-21 encourages States to consider systemic safety improvements as they update their strategic highway safety plans.

"The systemic approach is well suited to address fatalities that are widely distributed on the highway system, such as the Nation's rural and local systems, which are parts of our national system that have a large percentage of fatalities and serious injuries," says Associate Administrator Tony Furst of the Federal Highway Administration's (FHWA) Office of Safety. "It presents an excellent platform to engage our local partners in a 'toward zero deaths' vision."

Most of the existing safety management resources focus on the traditional site analysis approach and methodologies that support data analysis to identify high-crash locations. Recognizing the need to address the lack of analytical techniques and models that emphasize the systemic approach, FHWA developed the Systemic Safety Project Selection Tool. What follows is an overview of the systemic approach and how States can use it to prioritize safety improvements.

Description of the Systemic Process

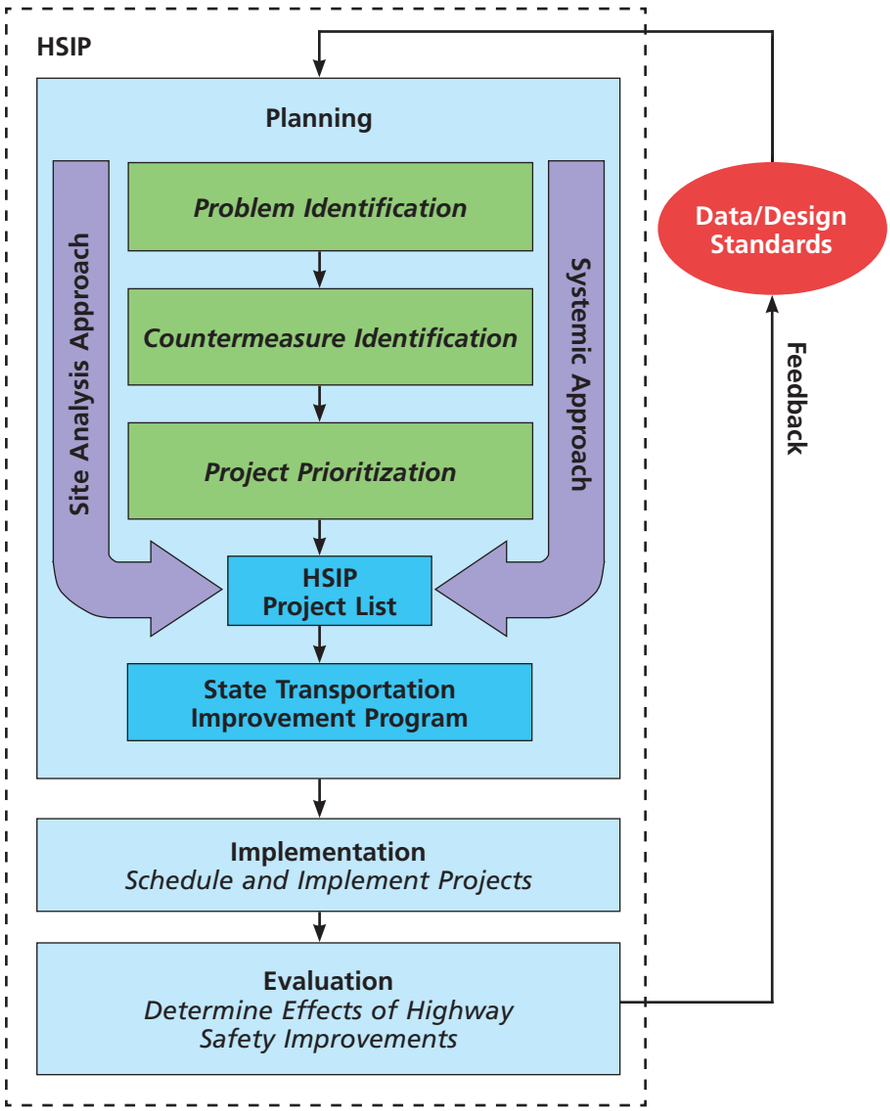
The Systemic Safety Project Selection Tool is a cyclical process outlining a series of steps that build on the priorities established in State strategic highway safety plans. The process helps identify the *characteristics* of locations with severe crashes to support application of safety improvements throughout a roadway system.

The tool builds upon current practices and consists of three elements:

- Element 1: Conducting a systemic safety analysis
- Element 2: Balancing systemic and traditional safety investments
- Element 3: Evaluating the effectiveness of a systemic safety program

FHWA designed the selection tool to be flexible and applicable to a variety of systems, locations, and crash types. The process is meant to be easy to use and straightforward, requiring minimal training and technical assistance. FHWA designed the tool's outputs to be understandable to both program managers and project development engineers who may or may not have been trained in techniques for traffic safety analysis. Further, FHWA designed the tool to be adaptable, so individual agencies can modify

Highway Safety Improvement Program (HSIP) Process



Source: FHWA.

the tool's data requirements depending on the availability of local data.

Element 1: Conducting a Systemic Safety Analysis

One key to systemic safety planning is evaluating an entire system using a defined set of criteria, which will vary depending on the types of data available. The result is an inferred prioritization, indicating that some elements of the system (those sites with more risk factors present) are more promising than other candidates for safety investments. One key question this process sets out to answer is this: Do all systems and crash types present equal opportunities for crash reductions, or do specific parts of the system and certain crash types offer greater opportunities for reductions? The process of systemic safety planning involves four steps that will answer these questions and result in identifying and prioritizing safety improvement projects.

The systemic safety approach involves identifying a problem, selecting a countermeasure, and prioritizing improvement projects. It starts with different criteria to identify sites with the greatest potential for safety improvement that might lead to a different set of projects. This approach involves looking at systemwide data to analyze and identify systemic safety problems—basically, large numbers of specific crash types that are scattered across a system with very low crash densities. The approach involves performing microlevel analysis to conduct a risk assessment of network locations. This analysis uses crash data along with site characteristics and traffic data to identify sites with a greater risk for crashes. This process leads to the selection of relevant mitigating strategies that are most appropriate for broad implementation across those locations. The following four steps are involved in this process.

Step 1. The first step is to conduct a systemwide analysis of crash data to identify the sites whose target crash types are associated with the greatest number of injury and fatal crashes, which may also be the sites with the greatest potential for safety improvement.

After selecting the target crash types, the next task is to answer the question: What are the characteristics of the locations where the target crashes are occurring? One useful approach and tool for this analysis is creation of a "crash tree" diagram, which can take a number of different formats, depending on the capabilities of the DOT's system for storing crash records. A typical crash tree might include information such as the jurisdiction (State or local), general location (rural or urban), roadway type (freeway, expressway, or conventional two-lane road), segment or intersection, and type of intersection control. The crash tree helps engineers identify and select the facility types and roadway and traffic control characteristics of the locations where the target crash types occur most frequently.

The final task in this step is to identify and evaluate the risk factors. This effort further defines the selected facility types by documenting the most common characteristics of the locations where crashes occurred. For example, if the previous tasks suggested a focus on road departure crashes on rural two-lane segments, this task might reveal that these crashes are overrepresented on roads that have a curvilinear alignment, poor road edges, and a specific range of traffic volumes. The two previous tasks relied on data typically available in crash

records systems, as reported by law enforcement. The task of evaluating risk factors, however, generally requires road and intersection inventories to provide additional levels of detail. In situations where such inventories are unavailable, the Systemic Safety Project Selection Tool provides more information on how States can identify risk factors using video logs, online aerial imagery, or windshield surveys.

Step 2. The next step is to screen and prioritize locations that could benefit from systemic safety improvement projects. This involves conducting an assessment of the roadway elements for the focus facilities identified in step 1 to determine the presence (or absence) of the contributing risk factors at each location. The more risk factors present may indicate a higher risk and, therefore, a higher priority location for safety investments. The outcomes of this step are a risk assessment and rating of the focus facility types.

Step 3. The third step involves assembling a comprehensive list of potential countermeasures and evaluating each one to narrow the list down to a select few high-priority strategies targeting the focus crash type on the prioritized network elements. Given that the systemic approach involves deploying strategies widely, the selection process focuses on countermeasures that are low cost and proven effective. This step yields two key outcomes: (1) a short list of effective, low-cost countermeasures for each focus crash type that will become the target of the safety projects that follow; and (2) documentation of important characteristics of each strategy, such as whether it is tried and proven, expected effectiveness, estimated implementation and maintenance costs, and consistency with an agency's policies and practices.

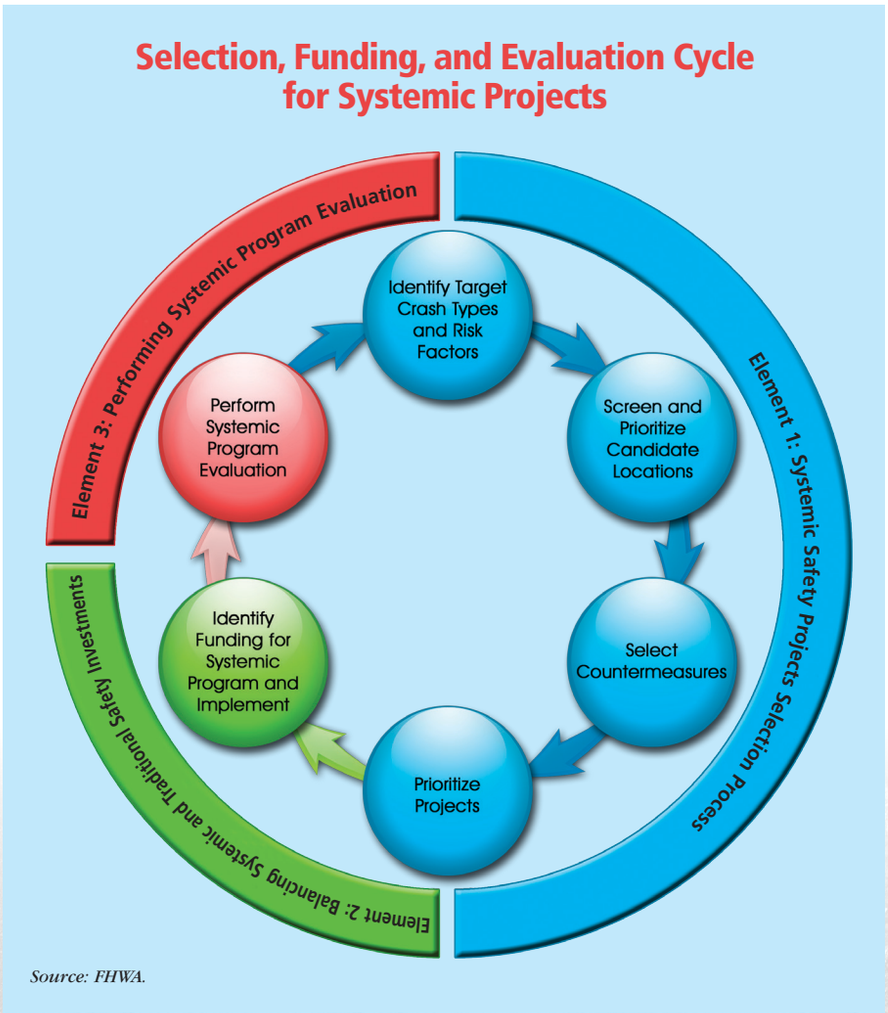
Step 4. The final step in element 1, conducting a systemic safety analysis, is deciding on the list of safety improvement projects using the prioritized at-risk locations identified in step 2 and the final countermeasures selected in step 3. To provide a measure of consistency in assigning countermeasures for widespread deployment, engineers may want to use a simple set of criteria considering factors such as traffic volume, environment, adjacent land uses, or roadway cross sections. Unlike the traditional site analysis approach to safety planning, which identifies the single best countermeasure for each individual location, the systemic approach considers multiple locations with similar crash and risk characteristics, and selects a preferred set of countermeasures suitable and affordable for widespread implementation. The primary outcome of this step is the identification of one or more countermeasures for each of the at-risk candidate locations along a system of roadways. Together, the individual projects comprise the jurisdiction's systemic safety program.

The new element in the selection process is using the risk factors as a surrogate for severe crash experience. Agencies that have networks with low crash densities can rely on the risk factors to improve locations proactively, before a severe crash occurs, rather than reacting and implementing projects after someone is killed or severely injured.

Pilot Testing

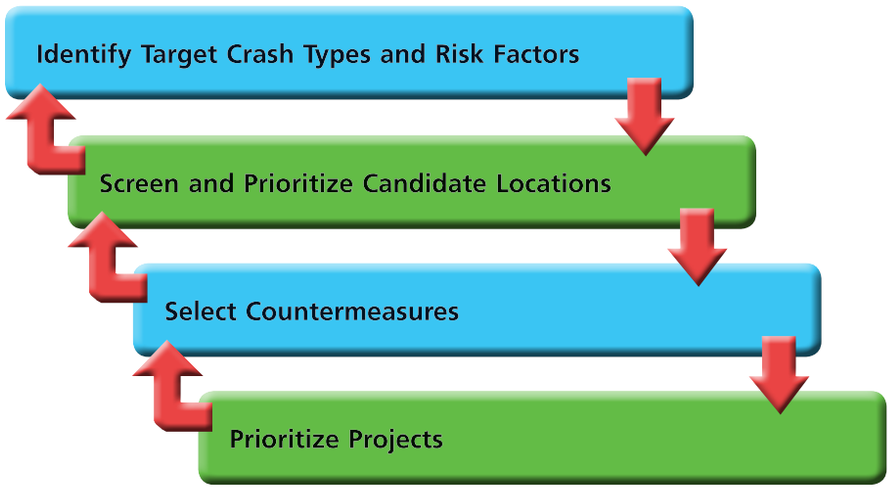
Before moving on to the second element, it might help to look at a pilot test of conducting a systemic analysis to clarify the process. One of the strengths of the systemic process and the use of risk factors is that an agency can easily adapt the analysis to work with its available data. In a pilot test, the Kentucky Transportation Cabinet, New York State Department of Transportation, and Thurston County Public Works Department in Washington State each selected a similar focus facility and crash type, but used different risk factors to select priority locations. Despite choosing similar facility and crash types, the process used to evaluate and select risk factors varied across the three agencies.

Kentucky. The Kentucky Transportation Cabinet applied the systemic approach to 175 miles (280 kilometers) of county roadway (facility type) in six counties with a focus on road departure crashes (crash type)



Source: FHWA.

Selection Process for Systemic Safety Projects



Source: FHWA.

along horizontal curves. Staff from the University of Kentucky provided technical assistance with the identification and evaluation of risk factors, including traffic volume, access density, curve density for critical radius curves, presence of advance signing, intersections in the curves, and visual traps (where a crest vertical curve occurs before the beginning of the horizontal curve or when a minor road, tree line, or line of utility poles continues on a tangent). At the curves identified for safety improvements, Kentucky officials expect to assist the counties by deploying chevrons to delineate the curves.

New York. The New York State Department of Transportation applied the systemic approach by beginning with an analysis of the entire State roadway system for the purpose of identifying where specific crash types were occurring. Statistics on fatal and severe crashes were summarized using data from the State's Safety Information Management System, roadway inventory system, and geographic information system for the years 2007–2011. Researchers summarized the data based on jurisdiction and type of crash. The data showed that 30 percent of the crashes statewide were on the State system, 45 percent on the local system, and 10 percent on the county system. The remaining 15 percent were on other facilities such as parking lots, private roads, or unknown locations. The data also showed that lane departures were the most prevalent type of crash on the State system, accounting for 30 percent of crashes. Of those, approximately 37 percent took place on rural, undivided roadways.

A further analysis of the data revealed characteristics or risk factors common among a high proportion of the lane departure crashes. The risk factors analyzed included number of lanes, speed, traffic volume, shoulder width, lighting conditions, and curve radius. The highest incidents of lane departure crashes were shown to occur on rural, two-lane, undivided roads with a traffic volume between 3,000 and 6,000 vehicles and a posted speed limit of 55 miles per hour (88 kilometers per hour), and shoulder widths between 1 and 3 feet (0.3 and 0.9 meter). Curves with a radius of less than 300 also had a high proportion of crashes on these roads. New York is exploring the use of larger chevrons and true wet reflective pavement markings to improve safety at rural curves.

In addition, New York is using a systemic approach to improve roadway safety by placing centerline audible roadway delineators along approximately 3,000 miles (4,800 kilometers) of roadway over the next 5 years and installing pedestrian countdown timers to improve safety at intersections. The current HSIP program aims to spend 70 percent of the funding on site-specific projects and 30 percent on systemic projects.

Washington State. Thurston County applied the systemic process to determine that road departure crashes (crash type) were the most common along county arterial and collector roads (facility type). According to county staff, there are 365 miles (587 kilometers) of county arterial and collector roads. In addition, the county determined that 45 percent of severe crashes occurred along horizontal curves. County officials identified numerous potential risk factors but ultimately selected five for the risk assessment: speed differential, visual trap, intersections, presence of advance warning signs, and edge assessment.

Next, the county identified optional countermeasures, selected criteria for priority locations, and prepared an investment strategy using a prioritization and selection process similar to the one presented in FHWA's tool. Then the county applied for and received funding from the Washington State Department of Transportation to implement the countermeasures identified in the analysis. The installation of the countermeasures, including enhanced signing, rumble strips, delineators, and striping, is scheduled for summer and fall 2013.

"The systemic analysis is not driven by a particular crash at a particular location," says Scott Davis, the traffic engineering and operations manager for Thurston County Public Works in Washington. "Instead, the county has a proactive tool for planning and implementing low-cost safety countermeasures for signed horizontal curves. The county now can help our constituents by 'doing something' before the crashes occur. We cannot drive deaths to zero if we keep waiting for something to happen."

Element 2: Balancing Systemic and Traditional Safety Investments

The systemic component of a highway safety program requires an agency to determine how to divide its safety investments among projects identified through the traditional site analysis approach

and projects identified through the systemic risk assessment.

Exactly how to distribute the safety investments among candidate projects remains at the agency's discretion. For example, if an agency has many black spot locations—those with a high number of crashes—on its system, the agency might choose to direct more of its safety funds to site analysis projects. However, if road departure crashes are the target crash type, and if rural county highways are the priority facility type, the agency might opt to allocate a greater percentage of safety funds to systemic projects.

In 2009, the Minnesota Department of Transportation (MnDOT) began directing approximately 65 percent of HSIP funding to county roads. For the rural counties, the goal was to make at least 70 percent of these safety investments in systemic projects. However, the State was able to direct nearly all local safety funds to systemic investments.

"Minnesota recognized in our strategic highway safety plan that engaging counties was essential to significantly reducing the number of fatalities," says Sue Groth, MnDOT's State traffic engineer. "Identifying funding goals, including an emphasis on systemic projects for our rural counties, has been instrumental in reducing fatalities and saving lives. Through the systemic approach, more than $31 million has been invested in safety improvements on local roads."

The systemic approach provides program managers with the flexibility to respond to the needs of their roadway networks. After distributing funds and implementing projects, the managers can evaluate the projects and determine if the results are consistent with expectations. Are severe crashes trending downward, indicating a positive result? If the results of the safety investment were effective, the premise moving forward would be to continue on the same track. If the results were not in line with expectations, then the managers could consider a different distribution of safety investments.

Element 3: Evaluating The Systemic Program's Effectiveness

Performance evaluation provides useful feedback for decisionmaking and is an important part of the overall process to reduce the number of fatal and serious injuries resulting from crashes. Like systemic safety programs themselves, the practice of evaluating the effectiveness of these programs is relatively new and evolving. Implementing countermeasures in locations that have no recent crash history but exhibit other characteristics that indicate the potential for a severe crash carries challenges when it comes to performance evaluations, especially for specific locations or corridors. The primary challenge is that implementation is based mainly on risk factors and historical crash experience. Therefore, the key is to evaluate at a program level, not individual project sites.

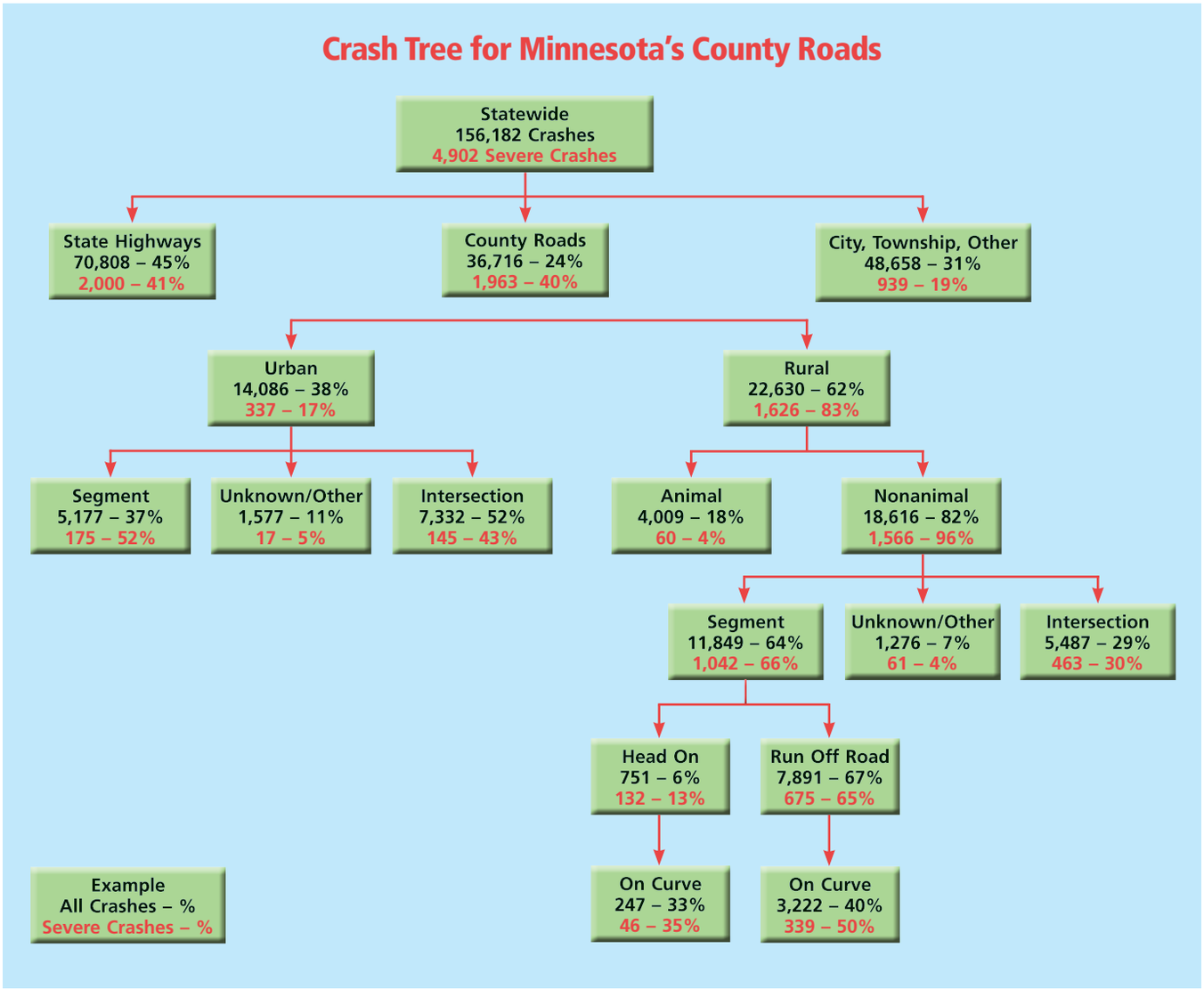
The Missouri Department of Transportation (MoDOT) recently applied the systemic process to low-volume paved roads in its State roadway system (facility type) and evaluated the results. Specifically, the State used a systemic implementation of edge lines for low-volume roads. "The systemic process identified the fraction of our system that was most at risk," says John Miller, MoDOT traffic safety engineer. "An evaluation across the entire system of improved corridors, rather than individual locations, demonstrated the potential for a net benefit from the investment."

Previously, MoDOT did not paint edge lines along the approximately 18,500 miles (29,770 kilometers) of these roads with traffic volumes less than 1,000 vehicles per day. However, analysis determined that the primary crash type (road departure) could be reduced with the addition of edge lines.

MoDOT's approach used traffic volume as the primary risk factor and determined that the majority of fatalities and serious injuries—approximately 570 per year—occurred along approximately one-third of the segments that had traffic volumes between 400 and 1,000 vehicles per day. A preliminary evaluation of the edge lines focused on the performance across the majority of eligible routes, 570

Thurston County Public Works, WA

This two-lane rural road in Thurston County, WA, shows roadside features and horizontal and vertical roadway alignments typical in the county.



This sample crash tree for Minnesota county roads shows that local roads—county, city, and township—account for more than half of severe crashes. On county roads, with 1,963 severe crashes in 5 years, the majority of crashes were road departures that occurred on rural segments. Further, most of these crashes occurred at horizontal curves. *Source: Minnesota crash records 2006–2010, not including the seven counties in the Twin Cities metropolitan area, Minnesota Department of Transportation.*

centerline miles (917 kilometers) that were subject to the safety improvement in 2009 within the Central District. Looking at the system of improved roads, instead of individual locations, the evaluators found that total crashes dropped by 15 percent (statistically significant at the 95-percent level), and serious crashes declined by 19 percent (not significant at the 90-percent level).

Systemic Process In Practice

Minnesota and Missouri pioneered the systemic approach and have completed the four-step planning process, resulting in the identification and implementation of safety projects using the risk assessment technique. MnDOT's application of the systemic process for county roads is unique in both the scale of the study and also for the fact that the State DOT performed the analysis for local agencies.

MnDOT applied the systemic approach in the preparation of safety plans for each of Minnesota's 80 rural counties, which had received virtually no safety investment based on the traditional site analysis approach. The genesis of this effort was MnDOT's strategic highway safety plan, which identified that approximately 50 percent of severe crashes in the State occurred on the 45,000-mile (72,420-kilometer) county system. Responding to a commitment in Minnesota's strategic highway safety plan to engage the counties in improving safety, MnDOT added a systemic component to its Highway Safety Improvement Program to fund projects on county roadways. The department also provided technical assistance to conduct the risk assessment of each county's system of roadways.

MnDOT applied the risk assessment in 80 rural counties on nearly 25,000 miles (40,233 kilometers) of rural paved county roads (facility type), which accounted for more than 80 percent of the severe crashes on local roads. Based on the crash data, MnDOT evaluated the

counties' 18,600 horizontal curves (facility type) to address the prevalent road departure crashes (crash type). In addition, department officials evaluated 12,000 rural through/STOP-controlled intersections, which accounted for approximately 30 percent of the severe crashes.

Because of the extremely low density of severe crashes (all rural segments, curves, and intersections averaged less than one severe crash per year), the risk factors used to prioritize these facilities included an evaluation of the road edge, traffic volume, and access density (number of entrances or exits to a street or highway per mile) for roadway segments. For curves, the risk factors included radius and the presence of visual traps. For intersections, the risk factors were skew, presence of commercial development, and proximity to the previous STOP sign. The selected priority safety strategies included enhanced road edges with rumble strips and 6-inch (15.2-centimeter) edge lines, enhanced curve delineation (chevrons), and upgraded traffic signs and streetlights for intersections.

In Minnesota's seven urban counties, the assessment focused on 1,300 miles (2,092 kilometers) of urban roadways and approximately 2,800 intersections. Crash analyses identified angle crashes and conflicts involving pedestrians and bicyclists at signalized intersections as the target crash types. The selected priority strategies to improve safety included advance confirmation lights to assist in enforcement to curtail red-light running and the addition of an advance walk interval (which allows the pedestrian to begin crossing before the vehicle traffic on the parallel street is given the green light) and countdown timers at crosswalks.

The systemic process identified more than $235 million in safety projects for implementation along Minnesota's county highway system. Already, the State has implemented $31 million in projects funded by its Highway Safety Improvement Program.

Bringing It Home

Is your agency ready to adopt the systemic safety approach? FHWA's Office of Safety recently launched a Web site (http://safety.fhwa.dot.gov/systemic) that provides information for agencies looking to initiate or expand implementation of a systemic safety approach. Users can download the Systemic Safety Project Selection Tool and other resource documents from the site.

The site also includes information on the benefits and challenges associated with the systemic approach and step-by-step instructions, with examples, to guide users through the planning process. Other features include a discussion of risk factors associated with particular crash types and roadway characteristics, as well as case studies demonstrating the application of the systemic approach. Further, agencies can submit their own noteworthy practices to FHWA's online database through the site.

"The systemic approach to safety allows us to proactively address safety on our county road system," says Brian Roberts, executive director of the National Association of County Engineers. "We will continue to address our high-crash locations, but the systemic approach to safety provides a mechanism to widely deploy countermeasures across the county road system using a systematic, data-driven process."

Howard Preston, P.E., is a principal traffic and safety engineer with CH2M HILL in Mendota Heights, MN. He has a B.S. in civil engineering from Iowa State University.

Richard Storm, P.E., PTOE, is a project engineer working in traffic operations and safety with CH2M HILL. He has an M.S. in civil engineering from Iowa State University.

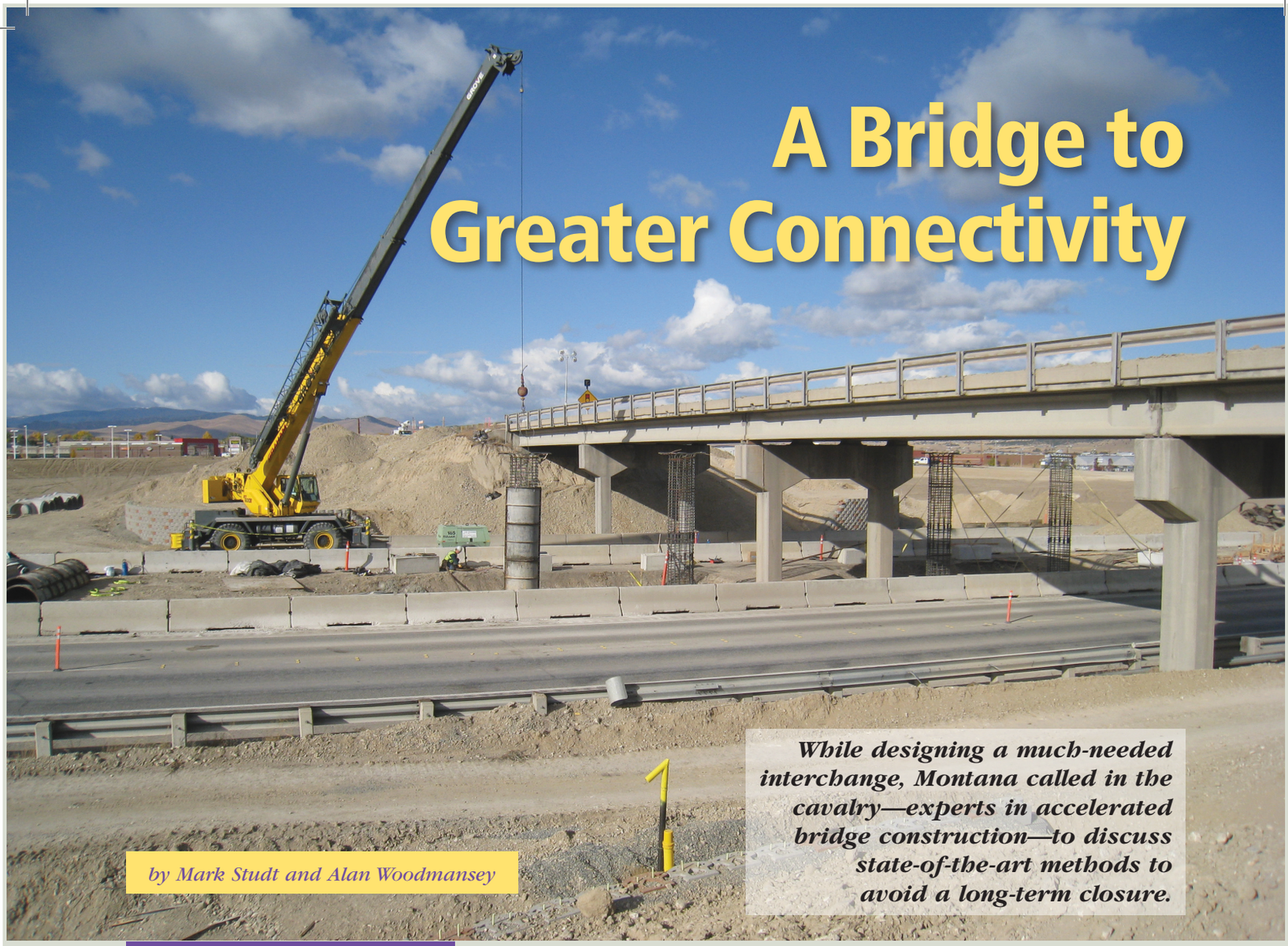
Karen Scurry, P.E., is the Highway Safety Improvement Program manager with FHWA's Office of Safety. She has an M.S. in civil engineering from Rutgers, the State University of New Jersey.

Elizabeth Wemple, P.E., is a senior associate at Cambridge Systematics. She has 20 years of experience as a transportation planner and traffic engineer, focusing on roadway safety management for State and local jurisdictions.

For more information, visit http://safety.fhwa.dot.gov/systemic or contact Karen Scurry at 609-637-4207 or karen.scurry@dot.gov.

CH2M HILL, Inc.

Where this paved road meets a rural road at a horizontal curve creates what safety engineers call a visual trap. The gravel road, from this perspective, gives the false perception that the paved road continues straight, when in fact it curves to the left.



A Bridge to Greater Connectivity

While designing a much-needed interchange, Montana called in the cavalry—experts in accelerated bridge construction—to discuss state-of-the-art methods to avoid a long-term closure.

by Mark Studt and Alan Woodmansey

(Above) The Montana Department of Transportation built a new interchange in Helena and a new Custer Avenue Bridge using innovative strategies recommended by industry experts at a workshop and conference hosted by the agency. Shown here is the old bridge still in service while drilled shafts for the new bridge are constructed.

The tale of the new Custer Interchange in Helena, MT, starts like many other transportation stories: population growth, aging infrastructure, changing land uses, increasing traffic. The Custer Avenue Bridge crosses over I–15 inside the urban limits of Montana's capital city. As a bridge along one of the few east-west routes that crosses the interstate, the structure could no longer meet the needs of its growing community. In fact, by 2003 the bridge was carrying more than 16,000 vehicles per day.

Another problem: The existing crossing offered no access between Custer Avenue and the interstate, a growing inconvenience to the increasing number of businesses setting up shop in the area. The solution? Replace the old bridge with a wider one, construct a new interchange to connect the two routes, and do it all while minimizing adverse impacts on nearby businesses, residents, and commuters.

"The greater Helena community really rallied around the need for increased accessibility—access to and from the interstate and Custer Avenue, and access from the interstate to the growing number of businesses in the area," says Ron Alles, Helena city manager. "Our challenge was meeting this need for a new interchange while replacing the old bridge and avoiding potentially costly traffic backups or lengthy detours."

Using standard procedures and contract requirements, the project would have required closing Custer Avenue for approximately 4 months, according to engineering estimates from the Montana Department of Transportation (MDT). Given the limited number of interstate crossings in the area, MDT quickly ruled out closing the bridge for that long. What to do?

Call in the experts. MDT officials invited industry experts to a technology transfer workshop and later a conference on accelerated bridge construction to help them sift through the growing number of technologies, tools, and innovations available to help get the job done faster. MDT added flexibilities into the contract that enabled its contractor to complete the bridge and interchange well ahead of schedule

and without major disruption to the community. In the end, the contractor employed mostly conventional construction techniques, but innovated and accelerated its work through ideas generated from the workshop and conference.

Changing Times

When Custer Avenue was constructed in 1955 as a two-lane road, the interstate did not yet exist. In fact, the area where the new interchange is now located was dotted with farmhouses, barns, and outbuildings—a far cry from today's growing commercial landscape.

Seven years later, in 1962, the State constructed the interstate and a bridge that carries Custer Avenue traffic over I–15. Although Custer Avenue provided a vital link between Helena and Helena Valley farms and ranches, the road carried very little traffic at the time the interstate was built, so ramps and an interchange to connect the two roadways were deemed unnecessary.

By 2003, the Custer Avenue Bridge had become functionally obsolete. In addition to lacking an interchange with the interstate, the bridge had no sidewalks or shoulders, presenting a barrier to mobility for bicyclists, pedestrians, and motorists alike.

In 2003 MDT completed an environmental impact statement for the I–15 corridor. A year later, the department signed a record of decision concluding that an interchange was needed at Custer Avenue. The interchange would provide access to I–15, improve east-west travel for all transportation users, create a safer roadway for bicyclists and pedestrians, and manage approaches to the ever-expanding commercial activity located along and near Custer Avenue by providing access to existing and projected land uses.

Soon after MDT decided to construct an interchange, commercial developers recognized the potential business opportunity and began preparing for the increased traffic exposure that would exit I–15 onto Custer Avenue once an interchange was built. However, preparations for commercial development began before MDT had final design plans for the roadway and interchange, which posed a potential risk for buildings being constructed in the right-of-way. To mitigate this risk, MDT and the city of Helena assisted the developers with determining where to position their facilities, including buildings and parking lots.

Technology Transfer Workshop

Design for the new Custer Interchange began in 2006 when MDT hired a consultant engineering firm. As the planning progressed, the need to minimize the impacts of construction on the Helena community became apparent. For example, in addition to minimizing traffic congestion and maintaining access to businesses, the project had to avoid interfering with public utility lines that run through the affected location. Due to the complexities of the project, MDT coordinated with the Federal Highway Administration (FHWA) to host an Accelerated Construction Technology Transfer workshop.

The workshop, held in January 2008 in Helena, occurred during the design stage. Transportation experts from the public and private sectors shared design ideas, insights into opportunities to reduce project impacts, and ways to mitigate potential problems. The workshop proceedings, documented in *Improving Connectivity: The Custer Interchange Project* (FHWA-IF-08-012), are available at www.fhwa.dot.gov/construction/accelerated/if08012.

"The workshop brought together some of the best and brightest national experts who interacted with the preliminary engineering team and the MDT construction engineering staff," says Mick Johnson, then MDT District Administrator. "It provided an array of options for consideration and inclusion into the design of this critical traffic element."

The major concern addressed during the workshop was how to reduce the duration of conventional construction to minimize impacts on the community. Acting on one of the recommendations from the workshop, MDT officials modeled the traffic impacts of conventional techniques for phased bridge construction,

This aerial view (left) shows the intersection of Custer Avenue (the smaller road running east-west) and I–15 prior to interchange construction. (Right) Shown here is the new Custer Avenue Bridge and interchange after construction. *Photos: Morrison-Maierle, Inc.*

which enabled traffic to use the bridge but with significant construction delays, compared to full closure of the Custer Avenue Bridge over I–15 and then analyzed the results.

Using CORridor SIMulation (CORSIM), a software program that performs traffic simulation, MDT found that a complete bridge closure would limit most impacts to just a couple of months versus conventional techniques, which would lead to greater congestion for a longer period of time. After sharing the simulation results with the local government and other stakeholders for feedback, MDT officials concluded that complete bridge closure offered the optimal solution.

Recommendations from the workshop also addressed the importance of building community support for the project and keeping the public informed. MDT created a Web site at www.mdt.mt.gov/custer to provide details, videos, and updates on the project. The department also worked extensively with the city of Helena, Lewis and Clark County, Helena Regional Airport Authority, and local business owners. For example, throughout the design phase, MDT held multiple public meetings for stakeholders to provide information and build community support for the project. Also, during the construction phase, MDT officials held weekly meetings with the public, which were well attended by nearby business owners and local media. The meetings provided opportunities for stakeholders to ask questions directly and resolve business concerns, while giving MDT engineers a chance to explain the work that would occur next.

"The weekly public meetings during the construction phase of the project were a key component of the overall public involvement process," says MDT District Construction Engineer Doug Wilmot. "MDT's project staff and the prime contractor were able to address all of the concerns brought forward by the public and resolve conflicts at the project level."

Conference on Accelerated Bridge Construction

With the benefit of reduced traffic impacts apparent, MDT explored other ways to expedite the bridge construction. To further develop ideas generated during the technology transfer workshop, the department hosted a conference on accelerated bridge construction in July 2009 with experts from FHWA and the bridge industry in attendance. The conference focused on proven techniques as well as newly introduced construction strategies.

Among the key concepts ultimately used in the project were the following:

- Use of incentives and disincentives in the construction contract based on costs to road users. Road user costs are calculated using factors such as number of cars and trucks, speeds, and detours.
- Construction of interstate ramps and placement of fill to widen and raise Custer Avenue while keeping the road open, thus reducing the time the bridge was closed.
- Designing flexibility into the contract to enable the contractor to choose between precast (pour concrete elements offsite and then move and set in place), cast-in-place (pour concrete in place), slide-in-place (build bridge superstructure next to existing bridge and then slide into place), or move-in-place (build offsite and transport to location) construction methods, if necessary and cost effective.

"The key to accelerating the bridge construction was providing flexibility to the contractor," says Kent Barnes, MDT bridge engineer. "To do that, we chose to design for acceleration and enable the contractor to simplify to conventional construction when necessary. For example, we provided design details for many precast elements and for bridge sliding. The contractor could choose to use these accelerated features or simplify to build conventionally to best fit the schedule demands of the overall project."

During the design phase, MDT also conducted a value engineering review in August 2009. The multidiscipline value engineering team analyzed ways to improve the value and quality of the project along with reducing the time needed to complete the project. The review team provided useful information regarding the sequencing of constructing the approach embankment and the bridge. The analysis showed that bridge construction could be accelerated so much that placement of the embankment fill would have to occur after the bridge was completed, which was not what MDT officials desired. The review made the project team aware of the need to balance the timing of the bridge and the embankment.

Final Design and Construction

MDT and its design consultant incorporated select concepts from the workshop, conference, and value engineering review into the final design plans. Following a recommendation offered during the

The old bridge has been removed from the center, leaving the two outer segments of the new bridge, shown here before the contractor constructed the center bridge lanes.

(Left) The completed new Custer Avenue Bridge over I–15.

(Below) The multiple lanes of the Custer Avenue Bridge are visible here, looking west on the new bridge.

in a much shorter timeframe. The Custer Avenue Interchange was not a "business as usual" project and it required flexibility within all phases. By showcasing the possibilities of accelerated construction, MDT and FHWA created momentum to move all levels of leadership to commit to completing additional design work that helped reduce time and impacts to the community during construction. In the end, combining a thorough design phase, including traffic modeling and stakeholder involvement, with a contract that offered flexible options for the contractor equaled a winning combination for MDT's Custer Avenue Interchange.

conference, MDT officials advertised the project contract for 6 weeks in summer 2011, increasing Montana's standard response time of 4 weeks. The additional time enabled contractors to consider the complexities of the project and the various options for bridge construction before proposing their recommended solutions. The agency awarded the $23 million contract in August 2011.

MDT included three construction phases in the contract, with the first two phases offering incentives for finishing early and disincentives for exceeding deadlines. The first phase improved the detour route before bridge closure, the second included the bridge closure and replacement, and the third involved all remaining contract work such as opening the interchange ramps. MDT also decided upon a 75-day period for the bridge closure phase, with up to 35 days eligible for incentives of $14,500 per day.

Because the new bridge is wider, the contractor could build the new sections on both sides of the old structure and then close the bridge only to tear down and rebuild the center section. Therefore, before closing the old bridge, the contractor installed the outside bridge piers, columns, and deck beams for the new bridge just outside the footprint of the existing structure. The contractor also built up the embankment fill before the bridge closure.

Using mostly conventional techniques and taking advantage of the flexibility afforded in the contract, the contractor was able to complete much of the remaining work prior to closing the road and removing the old bridge. Ultimately, the contractor completed the bridge replacement 35 days ahead of the allotted 75 days and received the maximum incentive amount.

Jack Carlson, MDT

The bridge and interchange opened to traffic on May 23, 2012. In June 2012, U.S. Senator Max Baucus and then Governor of Montana Brian Schweitzer attended a formal opening ceremony.

"The speed [at which] this project was constructed is a testament to all [who] were involved and can prove that working together, we can streamline the process, while ensuring that quality is maintained," FHWA Division Administrator Kevin McLaury said during the ceremony.

Conclusion

By hosting an Accelerated Construction Technology Transfer workshop, MDT was able to hone in on the best options for completing the interchange project

Mark Studt, P.E., is a consultant project engineer for MDT. Studt was the State's consultant design project manager for the Custer Interchange. He has a B.S. and M.S. in civil engineering from Montana State University.

Alan Woodmansey, P.E., is an operations engineer in the FHWA Montana Division. He is the Federal oversight engineer for the district where the Custer Interchange is located. He has a B.S. in engineering from the United States Military Academy and an M.S. in engineering management from the Missouri University of Science and Technology.

For more information, contact Mark Studt at 406-444-9191 or mstudt@mt.gov, or Alan Woodmansey at 406-441-3916 or alan.woodmansey@dot.gov.

How Does Transportation Affect Public Health?

by Eloisa Raynault and Ed Christopher

Organizations across the country increasingly are looking at the important relationship between the two disciplines.

According to the Centers for Disease Control and Prevention (CDC), an estimated one in three adults and almost 17 percent of young people in this country are obese. Because the transportation system helps shape how communities are designed and operate, it can have a profound influence—both positive and negative—on public health.

The benefits of physical activity are well known: Exercise, including "active transportation" activities like walking and bicycling, can help prevent weight gain and lower the risks of obesity, diabetes, and heart disease. According to the U.S. Department of Health and Human Services' *2008 Physical Activity Guidelines for Americans*, "although some health benefits seem to begin with as little as 60 minutes (1 hour) a week, research shows that a total amount of 150 minutes (2 hours and 30 minutes) a week of moderate-intensity aerobic activity, such as brisk walking, consistently reduces the risk of many chronic diseases and other adverse health outcomes."

Where transportation infrastructure is designed to accommodate or even encourage nonmotorized transportation, such as through complete streets policies, it can have a positive effect on public health. In its research report, *Planning Complete Streets for an Aging America*, AARP notes that "the ability to live closer to daily destinations is an important factor in maintaining mobility among older people who cannot drive or whose driving is limited. People 65 and over living in areas where houses are built closer to shops and services are less likely to stay home on a given day, and are more likely to use public transportation and walk to get around."

The connections between public health and transportation are varied and well documented in peer-

Cyclists enjoy Ben Butterworth Parkway, part of the national Mississippi River and American Discovery Trails, here shown in Moline, IL, during the Quad Cities in Motion Week. Numerous States and metro areas are taking steps to consider active transportation and public health in their planning processes. *Photo: Bi-State Regional Commission.*

reviewed journals in both the public health and transportation arenas. A 2010 CDC study, for example, calculated that the costs of medical care and lost productivity associated with motor vehicle crashes exceeded $99 billion in 2005.

Another study, out of the University of California, Berkeley's Safe Transportation Research & Education Center, found significant health disparities in the area of transportation safety, with African-American, Native American, and Latino drivers facing higher traffic-related risks related to seatbelt use, impaired driving, and pedestrian safety. Further, research has shown that limited access to transportation creates health inequities, as well as decreased access to education, employment, and opportunities for recreational activities for older adults and people with disabilities.

Transportation also is a source of pollution, generating air, soil, water, and noise pollutants, including particulate matter, carbon monoxide, nitrogen oxide, and carcinogens. Reports by the American Public Health Association and others have linked air pollution to negative health outcomes, including asthma, respiratory illness, heart disease, poor birth outcomes, cancer, and premature death.

To overcome these challenges, many in the transportation field are collaborating with colleagues in public health to research topics such as air pollution, safety, physical activity, and access to goods and services that support healthful living. This spotlight on public health and transportation complements other trends across the country, such as greater interest in alternative modes of transportation, livable communities, and resource conservation.

Complete streets and land use strategies that consider health can help increase physical activity, improve accessibility and safety, and ease congestion and air pollution. "As the use of these strategies increases," says Andrew Dannenberg, an affiliate professor at the University of Washington's School of Public Health, "there is tremendous potential for studying how health outcomes may be improved via transportation."

The case studies below, culled from across the country, help illustrate how metropolitan planning organizations (MPOs) and States are collaborating at the crossroads of public health and transportation.

Public Health on The MPO Front

MPOs are federally mandated bodies for urban areas larger than 50,000 people and are responsible for the transportation planning for their areas. By law, MPOs serving urbanized areas with more than 200,000 people must have policy boards composed of local elected officials, State department of transportation (DOT) representatives, and the providers of major modes of transportation, including transit services and airports. All MPOs must have policy boards that include local elected officials. MPOs decide how Federal transportation funds for their areas will be spent, thus playing a major role in setting transportation policy and approving different types of transportation facilities.

Many MPOs are becoming concerned about the effects of their plans and programs on public health. Regional plans like the one published in 2010 by the Chicago Metropolitan Agency for Planning now call for "pursuing opportunities for more compact, walkable, and mixed-use development," and making "significant, criteria-based investments in parks and open space" as a means to achieve "major benefits . . . including enhanced quality of life" and "improved public health through the promotion of active lifestyles."

Around the country there are countless examples of MPOs explicitly incorporating public health into their planning, policy, and project selection processes. In a December 2012 report, *Metropolitan Area Transportation Planning for Healthy Communities*, the Federal Highway Administration (FHWA) documented the efforts of four MPOs—those in Nashville, TN; Seattle, WA; Sacramento, CA; and San Diego, CA—that are successfully considering aspects of health during the transportation planning process. What follows are highlights from that report, as well as a summary of similar efforts in San Francisco, CA, and in a Midwestern region known as the Quad Cities, which includes cities in Illinois and Iowa along the Mississippi River.

Nashville Area

As described in the FHWA report, in December 2010, the Nashville Area MPO adopted its 2035 regional transportation plan, which made a significant shift from prior plans to implement active transportation projects. Of the 100 points of evaluation

Eloisa Raynault, APHA

This vibrant street in San Francisco, CA, shows various multimodal transportation options that can increase opportunities for physical activity and reduce air pollution.

Nashville Metro Planning Department

Participants gather for the start of the annual Tour de Nash, a community bicycle ride and walk that regularly draws more than 1,000 locals who enjoy Nashville's greenway, bikeway, and sidewalk networks.

criteria used to rank transportation projects, 60 deal with issues such as improving air quality, providing walking and bicycling facilities, reducing injuries for all modes, improving personal health, and ensuring equity of access to transportation facilities in underserved areas.

Five hundred transportation projects were submitted for the plan, and the MPO ranked them using the new criteria. Officials also reviewed the projects for proximity to community destinations such as schools, parks, community centers, and grocery stores. Seventy-five percent of the roadway projects submitted included an active transportation element such as a bikeway, sidewalk, or greenway. In the final plan, 70 percent of the adopted roadway projects included infrastructure for active transportation, up significantly from the estimated 2 percent in the 2030 plan adopted in 2005.

In 2012, the Nashville Area MPO launched a regional household travel survey asking representatives from 6,000 households to report their travel behavior and its subsequent impacts on their health. A subset of 600 participants wore devices that collected information on physical activity as part of daily travel. Transportation planners will use the data from this landmark study to shape additional tools and policies on health outcomes in the next update of the regional transportation plan.

"Planners and local decisionmakers are beginning to have a more holistic understanding of transportation facilities," says Leslie Meehan, director of healthy communities for the Nashville Area MPO. "On the health front, multimodal transportation facilities can supply opportunities for routine physical activity as part of the daily commute, [as well as] better air quality, improved social connections, fewer collisions, and access to fresh food. The profession of transport planning has an obligation to work in concert with the profession of public health, measuring and enabling positive health impacts, while mitigating the negative through more strategic decisionmaking."

Seattle Area

In the Seattle area, the Puget Sound Regional Council is forging a strong connection between transportation, public health, and the environment through programs focused on active transportation, climate change, and access to healthy food. The council's work in the health area has evolved in coordination with efforts at a variety of local and State agencies.

According to Charlie Howard, the council's director of integrated planning, "Some of our early work in the health arena centered on air quality, congestion management, safety, and greenhouse gas emissions, which all have health implications. Most recently, we are working with our various county health departments, as we share many cobenefits. For example, improving air quality reduces rates of heart disease, asthma, and stroke,

SANDAG

As part of a fresh approach to its Safe Routes to School campaign, SANDAG collaborated with the U.S. Department of Health and Human Services, San Diego County's Healthy Works program, and a design studio to develop collectible trading cards for kids focused on bicycle and pedestrian safety. Here, the cards are being handed out at a school event.

SANDAG

Printed in both English and Spanish, SANDAG's collectible trading cards illustrate examples of unsafe bicycle and pedestrian behaviors.

while increasing physical activity reduces obesity and heart disease."

The council has begun to refine its approach to bicycle and pedestrian planning with a focus on promoting active living. And, for the next long-range transportation plan, the council's board has asked staff to incorporate health into the measures used to prioritize projects.

Sacramento Area

In general, MPOs and cities in California tend to be hotbeds of health activities, especially those that involve transportation initiatives. FHWA's report highlights ongoing efforts in two California metropolitan areas: Sacramento and San Diego.

The Sacramento Area Council of Governments (SACOG) reports facing two major public health issues related to transportation: surface ozone and obesity. In some of its earlier work, SACOG's air quality initiatives focused on adopting clean engines. However, in recent years, the council has expanded its focus to include active transportation, transit-oriented development, and transit services to help disadvantaged populations reach essential destinations like medical facilities and food services.

SACOG is working to make public health front and center in its long-range transportation plan by putting it in context with equity, housing, safety, air quality, public transportation, and bicycling and walking. The draft plan also identifies a number of strategies that aim to incorporate public health into project selection, with measures that focus on transit access, active transportation, and reducing vehicle miles traveled as a means to improve air quality and public health.

Further, the council is the recipient of a 2010 Sustainable Communities Regional Planning Grant from the U.S. Department of Housing and Urban Development. SACOG is using the grant for projects to increase transit-oriented development and improve the quality of life in the region. One of the working groups under the grant is focused on equity, housing, and health, with a subfocus on access to health care.

San Diego Area

In southern California, the San Diego Association of Governments (SANDAG) represents 18 cities and more than 3 million people. The MPO promotes physical activity and access to healthy foods by supporting compact, mixed-use, and transit-oriented communities with walkable streets and access to schools, parks, and grocery stores. Through a variety of policy documents, SANDAG offers a range of transportation options to meet the diverse needs of residents and businesses in the region.

For example, the 2050 Regional Transportation Plan and Sustainable Communities Strategy describes the link between public health and land use and transportation; promotes walkable, bikeable, and transit-oriented communities; and allocates resources to implement projects that will improve health outcomes in the region. The plan approves $6.5 million to fund early implementation of high-priority projects from the 2010 Regional Bicycle Plan. These projects aim to increase the number of people who bicycle in the region, as well as encourage the development of complete streets.

The MPO has received Federal and State grants to further its health-related activities, which include a program that provides incentives to local jurisdictions for Safe Routes to School initiatives and other efforts to promote public health. Recently, SANDAG awarded grants totaling $650,000 for activities related to pedestrian paths, sidewalks, connections to transit, food access, and urban agriculture.

In addition, partnering with the California Department of Public Health and the San Diego County Air Pollution Control District, SANDAG worked to develop a health assessment module for its activity-based travel demand model, used to analyze the region's transportation needs.

Another noteworthy activity is SANDAG's *Healthy Communities Atlas*. Published in March 2012, the atlas consists of a series of maps showing a spatial analysis of social and built-environment conditions known to affect health outcomes. The atlas uses existing data to develop health indicators at the U.S. Census block level. Various indicators plotted on the maps include access to sidewalks, parks, social support amenities, healthy food, and transit stations. SANDAG uses the atlas to identify areas that could benefit from policy initiatives and future investments.

SANDAG also has been one of the leaders in conducting health impact assessments, a process that helps evaluate the potential health effects of a plan, project, or policy before it is built or implemented. The association has provided training on conducting the assessments to more than 50 community members and professionals in the region.

Bi-State Regional Commission

All three public transit systems in the Quad Cities area have racks attached to their buses to encourage greater use of bicycles in commuting.

According to Stephan Vance, senior regional planner at SANDAG, "Looking at regional planning issues through the public health lens has helped us focus on active transportation, community design, and land use and transportation policies that can bring a broad range of benefits to the region, extending beyond improved access and mobility."

San Francisco Area

In the San Francisco Bay area, the Metropolitan Transportation Commission, with input from public health stakeholders, devised quantitative performance measures for health and equity that regional transportation planners can use. For example, the commission identified three performance targets for healthy and safe communities for its regional transportation plan—premature deaths from exposure to particulate emissions, injuries and fatalities from collisions, and average daily time per person spent walking or biking for transportation. The commission also analyzed impacts with respect to socioeconomic and geographic equity, with performance measures including vehicle miles traveled, travel time (commuting and noncommuting), and housing-transportation affordability.

At the county level, the San Francisco Department of Public Health has developed quantitative models for noise annoyance, vehicle-pedestrian collisions, and mortality attributable to air pollution, using inputs such as traffic volumes and population changes, which are routinely generated in the transportation planning process. The Department of Public Health coordinates with city and county transportation and planning agencies to provide information to support the inclusion of health impacts and health-promoting measures in planning and policymaking. These measures might include ventilation systems to protect air quality in residential developments near heavily trafficked roads or traffic calming on busy arterials that experience high numbers of pedestrian fatalities.

According to Dr. Rajiv Bhatia, director of environmental health for the San Francisco Department of Public Health, "We are at the beginning of a sea change in which transportation, planning, and public health professionals are collaborating on integrated performance measures to protect and promote health."

Quad Cities

Health-related transportation activities also are taking hold in smaller metropolitan areas, such as the Quad Cities region, which includes Bettendorf and Davenport in Iowa and East Moline, Moline, and Rock Island in Illinois. (Bettendorf, the fifth of the Quad Cities, grew large enough for inclusion during the 1970s, but the name "Quad Cities" was already well known and remained in use.) The Bi-State Regional Commission, which is the MPO for the Quad Cities area, serves a population of just over 400,000 and is involved with a variety of health activities.

Staff members from the MPO participate in a program called the Quad City Health Initiative, an organization-based effort that aims to create a healthy community through outreach, awareness, advocacy, and program funding for a variety of health-related activities. For example, the MPO helps coordinate QC in Motion Week, promoting use of alternative transportation and bike-to-work events.

Like many MPOs, the agency has complete streets initiatives underway, which stem from a complete streets policy adopted in 2008. Projects that have grown out of this policy include a bicycle plan for Rock Island, formation of a team focused on alternative transportation in the city of Moline, and efforts in Bettendorf to review city codes and ordinances related to multipurpose trails and sidewalks.

Another area where the MPO is active is in facilitating greater access to local food systems. For example, in cooperation with its transit agencies, the Bi-State Regional Commission produced a system guide feature called "What ROUTE is it on?" that lists the

MassDOT

More than 300 Massachusetts students from kindergarten through the eighth grade walked around the Boston Common on October 3, 2012, to celebrate MassDOT's Safe Routes to School program on International Walk to School Day. MassDOT partners with more than 500 elementary and middle schools across the Commonwealth to deliver the program.

Dan Clever, Triangle Rails to Trails Conservancy

Construction of bridge supports is underway for a new pedestrian crossing that will carry the American Tobacco Trail over I–40 in Durham, NC.

services and vendors within walking distance of local transit stops.

Public Health At the State Level

In addition to health-related activities at the MPO level, many States are taking steps to consider the health effects of transportation in the planning process. Some notable efforts are underway in Massachusetts, Minnesota, and North Carolina.

In June 2009, State legislators signed into law the Massachusetts Healthy Transportation Compact, which put in place an interagency initiative to facilitate transportation decisions that balance the needs of all transportation users, expand mobility, improve public health, support a cleaner environment, and create stronger communities. The State's secretaries of transportation and health and human services cochair the compact, which also includes the secretary of energy and environmental affairs, the Massachusetts Department of Transportation's (MassDOT) highway administrator, the MassDOT transit administrator, and the commissioner of public health. To achieve the compact's goals, the department is forming partnerships with the public and private sectors, advocacy groups, and transportation, land use, and public health stakeholders.

"What is key is that these partnerships are breaking down traditional policy silos and inspiring innovation at all levels to advance healthy transportation outcomes," says Catherine Cagle, MassDOT's manager of sustainable transportation.

In October 2012, MassDOT Secretary Richard Davey announced a statewide goal of tripling the share of travel in Massachusetts by bicycling, transit, and walking, further affirming the State's interest in promoting active transportation.

Minnesota GO, A Visioning Process

Over the past few years, the Minnesota Department of Transportation (MnDOT) has been shifting gears to acknowledge how the transportation system affects chronic diseases. In November 2011, MnDOT launched the Minnesota GO visioning process to better align the transportation system with what Minnesotans expect for their quality of life, economy, and natural environment.

According to Tim Henkel, assistant commissioner for modal planning and program management at MnDOT, "The effort is based on an understanding that transportation is a means to other ends, not an end in itself. It also recognizes that infrastructure is only one of many elements necessary to achieve a high quality of life, a competitive economy, and a healthy environment."

As part of the Minnesota GO process, the department established a collection of guiding principles, one of which was the need to "leverage public investments to achieve multiple purposes." This principle recognizes that "the transportation system should support other public purposes, such as environmental stewardship, economic competitiveness, public health, and energy independence."

The vision statement goes on to address public health explicitly, as a challenge that will affect transportation in the State over the coming decades: "The increased frequency of several chronic diseases related to obesity—heart disease, diabetes, and cancer—coupled with an aging population, places enormous strains on the ability to pay for health care. Unless significant measures are taken, the deaths, diseases, and health care expenditures attributable to physically inactive lifestyles will only increase. Regular and sustained physical activity can help Minnesotans lead healthier lives. Health advocates will continue to push and recommend more active lifestyles and higher levels of daily physical activity, including through transportation choices such as biking and walking."

North Carolina's Mission Statement

The North Carolina Department of Transportation (NCDOT) has gone so far as to incorporate the word "health" into its mission statement. In April 2012, NCDOT expanded its mission to integrate public health considerations into its initiatives, plans, and policies, as well as to explore the use of health impact assessments. The revised mission statement reads: "Connecting people and places safely and efficiently, with accountability and environmental sensitivity to enhance the economy, health and well-being of North Carolina."

This expanded emphasis on public health culminated in October 2012, when the North Carolina Board of Transportation adopted a public health policy for the agency. Noting "a strong connection between the built environment and public health outcomes, including rates of chronic disease, obesity, levels of

Eloisa Raynault, APHA

Signs like these in Missoula, MT, help bicyclists navigate local trail systems.

physical activity, safety, and general well-being," the policy statement declares that "the North Carolina Department of Transportation may have opportunities to support positive health outcomes by considering public health implications in our decisionmaking across all transportation modes, programs, [and] policies . . . and through all stages of the life of a transportation project." Specifically, the agency will consider a "multimodal transportation system to provide access to and options for customers of all abilities and capabilities; safety for all users and all modes of transportation; and the potential for the transportation system to support human health."

Programmatically, NCDOT will explore accounting for health impacts and their costs and benefits throughout the processes of transportation planning, programming, and project decisionmaking.

FHWA Working Group

To complement efforts at the local and State levels, FHWA established an in-house working group in January 2012 consisting of staff representing 11 offices. The group's purpose is to explore how the agency addresses health-related issues and requests for information.

Although FHWA has no formal policy on health, agency officials recognize that public health is an integral part of transportation planning and program delivery and should be considered as part of decisionmaking in the public interest.

During its first year, the working group's accomplishments included defining health in transportation, identifying FHWA programs related to health, and developing an annotated bibliography of health-related resources. The group also created a health response team charged with responding to inquiries from State and local agencies.

An informal survey of planners at FHWA division offices in 2012 indicated that the agency is handling a number of questions on health-related topics:

- Considering public health in the long-range transportation planning process
- Reducing the severity and number of obesity cases through more walkable communities, complete streets, and livability goals
- Understanding health impact assessments
- Identifying infrastructure that supports or hinders transportation to human services
- Addressing urban food "deserts"
- Measuring response times for emergency medical services in congested corridors
- Assessing crash survivability in smaller electric or energy-efficient cars

In addition, FHWA's Office of Planning, Environment, and Real Estate recently launched a "Health in Transportation" section on its Web site and will soon offer answers to frequently asked questions, as well as links to related publications and training opportunities.

In its second year, the working group will coordinate its activities with the Office of the Secretary of Transportation, the Federal Transit Administration, and the National Highway Traffic Safety Administration, all of which hold a stake and interest in protecting public health.

"The working group has done an effective job compiling health in transportation information and improving their competency to provide technical assistance to the field," says Associate Administrator Gloria Shepherd, of FHWA's Office of Planning, Environment, and Real Estate. "We hope to advance the state of the practice by compiling and sharing this type of information with the MPOs and State DOTs as they consider it in the planning process."

Eloisa Raynault is the transportation, health, and equity program manager at the American Public Health Association, where she examines and tracks the impacts of transportation systems and policies on health and equity and shares resources on these topics with the association's 50,000-plus members and affiliates. She serves as cochair of the Transportation Research Board's (TRB) Health and Transportation Subcommittee. Raynault has a bachelor's degree in civil engineering from The George Washington University and a master's degree in natural resources with a focus on sustainable transportation from Virginia Tech.

Ed Christopher is a community planner with the FHWA Resource Center's Planning Team. He holds a bachelor's degree in political science and a master's degree in transportation planning from the University of Illinois at Chicago. Christopher also is active in TRB, where he cochairs the Health and Transportation Subcommittee, is an emeritus member of the Urban Transportation Data and Information Systems Committee, and has served on various other committees. Christopher recently has begun working to bring the worlds of transportation and public health closer together.

For more information, visit www.fhwa.dot.gov/planning/health_in_transportation or www.trbhealth.org, or contact Ed Christopher at 708-283-3534 or ed.christopher@dot.gov.

Shouldering the Load

by Gregory M. Jones

The use of paved shoulders as temporary travel lanes adds capacity when it's needed most.

Traffic congestion during peak periods is common on many urban freeways throughout the United States. The main cause? Increased traffic demand. According to the Federal Highway Administration (FHWA), between 1980 and 2003, annual vehicle-miles traveled increased by 89 percent, while total road miles grew by just 3 percent. The volume of traffic using many of the Nation's roadways now exceeds the capacity of the existing infrastructure.

As the discrepancy between vehicle-miles traveled and available capacity—as measured in freeway lane miles—grows, the problem of peak congestion is only worsening. In fact, researchers with the Texas A&M Transportation Institute, in their *2012 Urban Mobility Report*, found that travel delay in 498 U.S. urban areas increased from 1.1 billion hours in 1982 to 5.5 billion hours in 2011.

(Above) This highway in Germany allows hard shoulder running to provide additional capacity during peak travel periods, a strategy now gaining traction in the United States.

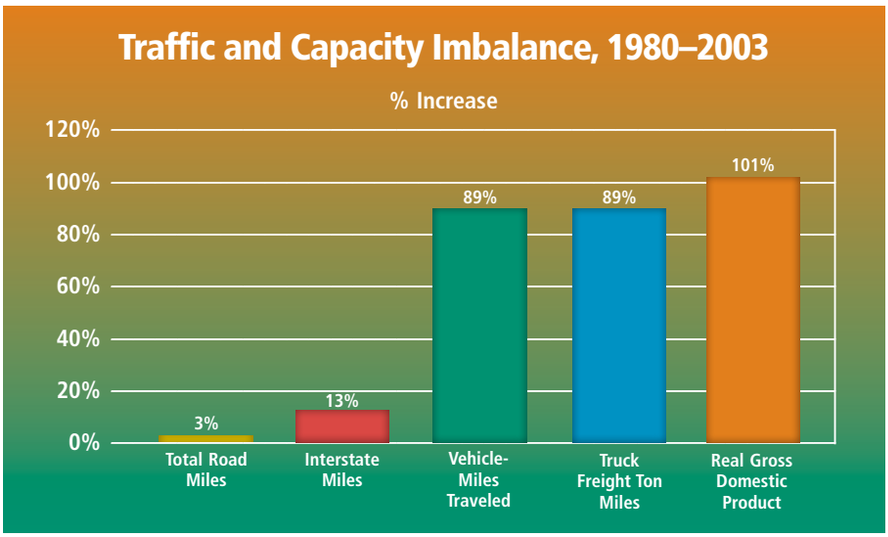
A number of factors limit the Nation's ability to build its way out of this problem. The lack of right-of-way, scarcity of funding, and environmental concerns limit construction of higher capacity facilities. Recognizing that these factors are unlikely to change in the near future, many metropolitan areas have begun to focus their resources on improving the flow of traffic on existing infrastructure.

To this end, departments of transportation (DOTs) are rolling out traffic management programs. The core elements of improving the efficiency of traffic flow are traffic management centers and intelligent transportation systems (ITS). Studies by FHWA and others have shown these deployments to be effective in reducing congestion related to incidents and planned special events, but tackling the recurring congestion that results when demand exceeds capacity remains an ongoing challenge.

One potential solution, already widely used in Europe, is the use of paved left or right shoulder lanes as temporary or interim travel lanes. Also known as hard shoulder running, this strategy can offer critical additional capacity to reduce recurring congestion. Researchers at FHWA recently studied the use of hard shoulder running overseas and in several applications here in the United States. What follows is a snapshot of how hard shoulder running works, sample U.S. deployments, and key operational and safety considerations.

A Tool for Active Traffic Management

The next generation of traffic management philosophy has begun to emerge under the banner of active transportation and demand



The interstate system comprises just over 1 percent of the Nation's total miles of roadway, yet it carries almost 25 percent of all traffic. As shown here, the growth in vehicle-miles traveled, truck freight-miles traveled, and real gross domestic product have far outpaced the growth in total miles and interstate miles of roadway capacity. *Source: FHWA Office of Policy.*

management. The principles underlying this philosophy are to implement strategies to improve the efficiency of traffic flow in conjunction with strategies that influence or adjust demand. The two sets of measures thus work in concert to help balance supply and demand.

Among the most prevalent strategies used to improve traffic flow is active traffic management. Deployments in Europe typically involve the use of overhead lane control signals to manage traffic flow. Road managers use the signals to display variable speed limits that help smooth traffic flow through congested conditions in an orderly manner. They also can display messages regarding dynamic lane closures and merge warnings when conditions warrant. With the ability to manage speeds in a harmonized manner, road managers can minimize instances of traffic flow breakdown caused by stop-and-go conditions that typically occur once a freeway reaches the level of saturation. In addition, they can provide advance warning to motorists regarding backups due to major incidents.

As reported in FHWA's November 2010 *Efficient Use of Highway Capacity Summary: Report to Congress* (FHWA-HOP-10-023), Europeans have used hard shoulder running for years in conjunction with overhead lane-control signals and variable speed limits in lane management systems. The dynamic use of breakdown shoulders as travel lanes helps add capacity to the system during times of critical need.

"By strategically identifying locations, using lane assignment technologies, and monitoring performance needs, the addition of temporary capacity through the use of shoulders as travel lanes will allow the active management of our roadways in a safe and efficient manner," says Robert Arnold, director of FHWA's Office of Transportation Management. "Europe has used hard shoulder running successfully for years as part of a suite of strategies to better manage its roadways."

In some cases, European transportation agencies have even retrofitted freeways with additional breakdown or pullout areas. These areas provide a safe refuge for vehicles that experience difficulties or are involved in minor incidents during periods when the shoulders are carrying traffic.

Bus-on-Shoulders Programs

To date, in the United States, the primary use of shoulders as temporary travel lanes has been by public transit buses that are bypassing slow traffic in the general-purpose lanes. Typically, this practice involves designating specific times of day that the shoulders operate as bus-only lanes.

The Minnesota Department of Transportation (MnDOT) began using bus-only lanes in 1992 and now has implemented the strategy on most freeways in the Minneapolis–St. Paul region. To date, MnDOT has more than 310 miles (500

Emergency pullouts adjacent to a shoulder use lane, such as this one in Great Britain, provide a refuge for stranded motorists when the shoulder is serving as a travel lane.

MnDOT

Minneapolis, an early adopter of using shoulders as temporary travel lanes, designates its freeway shoulders, such as this one, as bus-only lanes when speeds in the general-purpose lanes drop below 35 mi/h (56 km/h).

kilometers) of shoulder lanes for use by buses during designated times of the day.

According to MnDOT officials, use of these shoulder lanes has improved the ontime performance of the bus system significantly by providing reliable travel speeds at all times of the day and has made a significant contribution to increased transit usage across the metro area. The operating rules of the system allow buses to travel up to 15 miles per hour (mi/h) (24 kilometers per hour, km/h) faster than traffic in the adjacent general-purpose lanes, up to a maximum of 35 mi/h (56 km/h). If traffic is flowing at 35 mi/h (56 km/h) or faster, the buses simply stay in the general-purpose lanes. As this usage spread throughout the metropolitan area, MnDOT developed standards and guidance for use of the shoulders by the transit buses.

"Allowing buses to use the shoulders is a great example of agencies coming together, exploring options, and coming up with an inexpensive solution to getting the most people through congestion on existing infrastructure," says Carl Jensen, team transit manager at MnDOT. "Transit agencies that use bus shoulders have more reliable routes, which encourages more riders to use the bus. For MnDOT, more riders on the bus means [fewer] vehicles on the highways, which has many benefits including less congestion and pollution."

In addition to Minnesota, at least eight other States have implemented similar bus-on-shoulder applications: California, Delaware, Florida, Georgia, Illinois, Maryland, New Jersey, and Virginia. FHWA's *Evaluation of Operational and Safety Characteristics of Shoulders Used for Part-time Travel Lanes* (FHWA-HOP-12-008) notes the following examples of benefits for these types of applications:

- I–805/(SR 52) Connector in San Diego, CA: 5-minute travel-time savings and 99 percent ontime performance for buses using this 5.5-mile (8.9-kilometer) segment
- SR 400 in Georgia: 5- to 7-minute travel-time savings on this 12-mile (19.3-kilometer) segment

As noted in FHWA's *Efficient Use of Highway Capacity Summary: Report to Congress*, this operational strategy is generally a low-cost and quickly implemented solution that does not require costly expansion of highway right-of-way. Agencies can implement bus-on-shoulders programs on both highway and arterial corridors, but arterial applications often must rely on additional operational treatments, such as signal prioritization, in order to maintain a time advantage over regular traffic.

Fixed-Time Shoulder Use for All Traffic

To date, only a limited number of State or local agencies in the United States have opened the shoulder lanes to all traffic temporarily. Among those with the longest history are applications in Boston, MA, and northern Virginia. Each of these applications involves a peak-hour usage of the shoulder lane and use of roadside signage with specific times shown to alert motorists as to when the shoulder lanes are open to traffic.

Three freeways in Boston, I–93 (two segments), I–95, and (SR 3), allow the use of the shoulders during specific time-of-day operations. The inbound direction toward central Boston operates from 6 to 10 a.m. weekdays, while the outbound directions operate from 3 to 7 p.m. Only heavy trucks are prohibited from using the shoulder lanes.

When the Massachusetts Department of Transportation (MassDOT) began using the treatment in 2002, congestion on these facilities was so severe that traffic was at a standstill during peak periods, and frustrated drivers already had begun using the shoulders illegally. Today, MassDOT, the Massachusetts State Police, and the Commerce Insurance Courtesy Patrol assist with the operation of the shoulders.

With each deployment, MassDOT sought approval from FHWA to use the shoulder strategy as a temporary measure until the department could obtain funding and approval for widening the roadway to add a permanent travel lane. MassDOT constructed each shoulder lane to the standards of a traditional widening project, with drainage being moved to the new edge of the pavement, and guardrails and fixed-object shielding being shifted accordingly. The typical design is a 10-foot (3.1-meter) minimum width and a 12-foot (3.7-meter) desirable width. Crews removed the scored concrete, rumble strips, and block pavers in the process. To provide refuge in case of incidents, MassDOT installed emergency pullouts approximately every 0.5 mile (0.8 kilometer) along the deployment sections.

In northern Virginia, a temporary shoulder lane application along I–66 just outside Washington, DC, was first implemented in 1992 between U.S. 50 and I–495. It operates during

During peak hours, three freeways in Boston, including this one, allow use of the shoulder as a temporary travel lane. The yellow sign here lets motorists know that travel is permitted in the breakdown lane weekdays from 3 to 7 p.m.

specific hours as a shoulder use lane for all traffic. The eastbound lane operates from 5:30 to 11 a.m. weekdays, while the westbound lane operates from 2 to 8 p.m. Static signage indicates operating hours, while overhead signs above the shoulder lane display either a red "X" or a green downward arrow to inform motorists when the lane is closed or open to traffic, respectively.

Recently, two other notable shoulder use applications have begun operation as well: U.S. 2 in Seattle, WA, and SR 400 in Atlanta, GA. Both sites are open to all traffic and operate on a time-of-day fixed schedule. The SR 400 location initially opened as a bus-only shoulder lane in 2005 but was later opened to all traffic in 2012.

Dynamic Shoulder Use

At this time, only one application of dynamic shoulder use, somewhat similar to those in Europe, is in operation in the United States. On I–35W in Minneapolis, MnDOT operates a priced dynamic shoulder lane on a 1.6-mile (2.6-kilometer) section approaching downtown.

This application is distinctive in a couple of ways. First, when open to traffic, this lane is an extension of a price-managed lane. The recent expansion of I–35W extends the high-occupancy toll (HOT) lane in both directions for 18 miles (29 kilometers) south of downtown Minneapolis. During peak flows, the HOT lane permits carpool and transit vehicles to use it for free, while drivers of single-occupant vehicles can pay a toll to use the lane. In the northbound direction, right-of-way limitations precluded any widening on the last 1.6 miles (2.6 kilometers) into downtown. Thus, the shoulder is opened as a travel lane for this section.

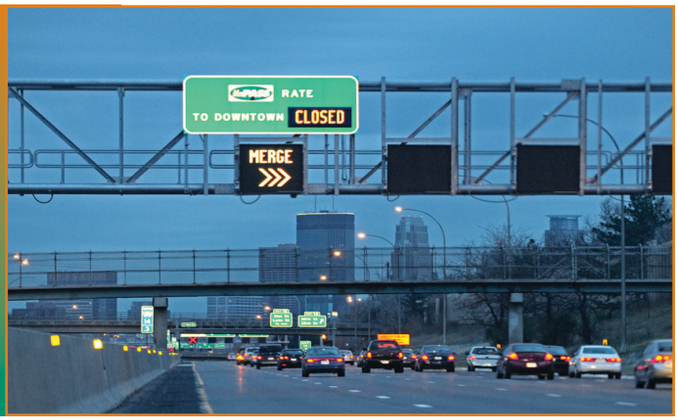
"Using the inside shoulder as a continuation of the HOT lane greatly improves the efficiency of the lane because it now extends to a major multilane exit into the downtown arterial network rather than ending 1.6 miles [2.6 kilometers] short and becoming a bottleneck in the freeway network," says Brian Kary, freeway operations engineer with MnDOT. "In addition, we were able to build this project for $17 million versus the full reconstruction to add a lane, which was estimated at $400 million. Also, the lane was added without increasing the freeway footprint, taking any right-of-way, or building any new infrastructure."

The other notable aspect of this application of shoulder use is the fact that MnDOT integrated it with the active strategies of lane management and variable speed limits, in a similar way to those applications in Europe. This combination enables MnDOT to open and close the lane dynamically when conditions warrant.

The U.S. Department of Transportation funded this first-of-its-kind deployment in the United States as a demonstration project under an Urban Partnership Agreement with MnDOT and the Twin Cities Metropolitan Council. The grant included funding for a detailed evaluation of the project's effectiveness, scheduled to be released in late 2013.

The I–35W application also is the only example of the left shoulder lane being used for this purpose on a freeway in the United States. The left shoulder operation is better suited for longer distance trips because it avoids having drivers navigate through areas where weaving occurs at entrance and exit ramps, which normally occurs to the right of travel lanes. The most complex design issue with a left-side shoulder use lane is finding an optimal way to terminate the lane while maintaining proper lane balance. In Minneapolis, the lane conveniently transitioned to a general-purpose lane prior to a major fork into the downtown arterial network. The creation of a bottleneck would have offset any upstream capacity benefits.

I–35W in Minneapolis, shown here, includes a priced dynamic shoulder lane in which drivers can pay a fee to travel during rush periods.



MnDOT

Operational Considerations

Right-side shoulder use lanes tend to have operational characteristics that are similar to those of auxiliary lanes, such as turn or merge lanes. Some of the deployments in the United States have continued the shoulder lane through interchanges, while others have opted to make the shoulder lane an exit-only lane at the interchange. DOTs typically implement bus-only shoulder lanes on the right side to allow for easier merging on and off the freeway.

FHWA's *Evaluation of Operational and Safety Characteristics of Shoulders Used for Part-Time Travel Lanes* (FHWA-HOP-12-008) found the functional capacity of most shoulder lanes to be approximately one-half that of a normal general-purpose lane. The limited functional capacity may be due in part to the geometric deficiencies, such as narrow width, close proximity of fixed objects, or lack of continuity associated with the lane, and to the fact that motorists may feel uncomfortable using the shoulder as a temporary travel lane. Speeds in the shoulder lane also tend to be 5 to 10 mi/h (8 to 16 km/h) slower than the adjacent general-purpose lanes. Research is underway at FHWA that aims to provide modeling capabilities for shoulder lanes, thus providing a potential benefit–cost analysis for future applications.

Until more specific guidance is available on how to design shoulders for use as temporary travel lanes, DOTs can look to the American Association of State Highway and Transportation Officials' (AASHTO) publication, *A Policy on Geometric Design of Highways and Streets*, commonly referred to as the Green Book. This publication provides general guidance on the geometric dimensions of roadways, including the widths of travel lanes, shoulders, and clear zones. Another AASHTO publication, *A Policy on Design Standards—Interstate System*, offers guidance related to standards for designing interstate highways.

When using the shoulder as a travel lane, the design standards need to be revisited. There will likely be no shoulder adjacent to the temporary travel lane. In addition, the vertical and horizontal offsets will need to be recalculated with the new edge of the travel lane being on what used to be the shoulder. A request for a design exception should consider the design, safety, and operational aspects of the proposed application.

VDOT allows use of this paved shoulder on I–66 in Fairfax County, VA, during peak periods. Static signage and dynamic overhead signs alert motorists as to when the shoulder lane is open to traffic.

Safety Considerations

Safety data on existing U.S. deployments are limited. The Virginia Department of Transportation (VDOT) has performed the most extensive safety analysis to date, focused on the I–66 application. VDOT reported on the analysis from this deployment in a 2007 article in the *Transportation Research Record* titled "Safety Impacts of Freeway Managed-Lane Strategy: Inside Lane for High-Occupancy Vehicle Use and Right Shoulder Lane as Travel Lane During Peak Periods." Also, VDOT's 2009 study "Seasonal and Operation Hour Extension Effect on Traffic Congestion: A Study of Northern Virginia's Interstate 66 Shoulder Travel Lane Practice" shared additional insights. The safety and operational results from these studies contributed to VDOT's decision to expand use of the I–66 shoulder travel lane to a dynamically triggered operation that will be implemented in response to congestion levels along the corridor. VDOT plans to deploy this tactic in conjunction with other advanced traffic management strategies, such as overhead lane control signals and variable speed limits.

In addition to reviewing crash rates, FHWA recommends that DOTs consider the potential effects on incident response. Many first responders use the shoulder as a way to bypass traffic queued at an incident. Some DOTs have mitigated this problem by providing additional motorist service patrols within the corridor.

Next Steps

The use of shoulders as temporary travel lanes is one of several strategies that researchers with the FHWA Office of Operations are studying under the formative program area of active transportation and demand management. The main focus areas for temporary shoulder usage are in conducting research in design, safety, operational characteristics, and modeling. In addition, the researchers are conducting a comparative analysis of European evaluations and research related to hard shoulder running. The resulting information will help FHWA shape any future policy or guidance documents.

Gregory M. Jones is a transportation operations specialist who splits his time working with the FHWA Resource Center in Atlanta, GA, as well as with the Office of Operations in Washington, DC. He has worked for FHWA since 1984. Jones provides national technical support in the areas of congestion pricing, managed lanes, active transportation and demand management, emergency transportation operations, intelligent transportation systems, freeway management, and regional operations partnerships. Jones has a B.S. in civil engineering from the University of Tennessee.

For more information, visit http://ops.fhwa.dot.gov or contact Greg Jones at 404-562-3906 or GregM.Jones@dot.gov.

The challenges of information accessibility have prompted efforts to digitize backlogs of transportation resources currently in analog formats.

Bridging the Digital Divide

by Paul R. Burley

Although transportation practitioners have access to a seemingly unlimited amount of information via Internet search engines and other online portals, a large portion of key research conducted before the digital age remains in print and other analog formats. This body of work remains difficult or, in some cases, impossible to access remotely, which may lead to duplication of research and, secondarily, loss of knowledge crucial to solving other transportation problems.

To provide practitioners with difficult-to-access materials, State departments of transportation (DOTs) and transportation libraries are working to digitize unique and important materials. Digitization is the conversion of analog materials, or documents that can be viewed or heard by *people*, to digital format, which can be read by *machine*. After digitization, a computer reads or interprets the file to produce an image for display or printing. Digitization does not necessarily represent an exact reproduction of the analog item; it is a snapshot of all or part of the document, sound record, or video.

And while most digitization projects yield a favorable return on investment, agencies and institutions can benefit from established workflows and examination of costs before undertaking such efforts.

Access: The Central Problem

Access to print and other analog transportation materials is hampered by the localization of resources at individual DOTs or research libraries and lack of discoverability, notably, the difficulty in finding these resources by means of standard Internet search queries. The access challenges may result in duplication of research, lack of knowledge of past research, or loss of historical and institutional knowledge.

Traditionally, transportation-related technical reports and other materials were available only to researchers in close proximity to the materials or to those willing to travel to the print collections. For example, a DOT's technical reports might be kept in a particular office in the DOT and are readily available only to practitioners in that department. Libraries have been used as repositories for print resources, but even under the best cooperative agreements, physical items remain largely available only to local users. Materials at local institutions often are not discoverable via search engines, library catalogs, or other means because of their physicality. Even at institutions with a well-cataloged collection, sharing agreements such as interlibrary loans are costly because of base fees, labor, and shipping. Though costs vary significantly by institution, a study by The University of Kansas and The University of North Carolina estimated borrowing costs of $12.11 per item across 23 North American libraries.

"The materials may exist, but the people who need them have no way to discover them," says Roberto Sarmiento, head of the Northwestern University Transportation Library. "We have a universe of information, but it is not necessarily available to the rest of the world."

The Digitization Solution

Digitization is one solution to the accessibility issue. When materials are digitized, practitioners can use resources regardless of their location. According to Sarmiento, "With digital objects, we may not

(Above) Mark Lorick, administrative coordinator in the Plans Storage Office with the South Carolina Department of Transportation, examines one of the 1.7 million plan sheets at the agency's warehouse. A recent digitization effort has made plan sheets accessible via computer and much less cumbersome. *Photo: Rob Thompson, SCDOT.*

even know who the user is, or where they're coming from. The user becomes anyone in the world searching for the information."

Digitized resources, depending on the quality of their associated metadata, such as author, title, and subject information, become discoverable via search engines and standard in-house library catalogs.

"We have a situation now where we're making these historical research findings available quickly," says Dr. Darcy Bullock, P.E., professor of civil engineering at Purdue University and director of the Joint Transportation Research Program, a collaboration of Purdue University and the Indiana Department of Transportation (INDOT). "Within hours of them being published online, we see Google Scholar™ pick them up."

However, providing access does not come without difficult decisions, such as which materials to digitize and procedures for digitization, as well as significant costs. A typical digitization project involves numerous steps. To start, the project planner selects materials for digitization. Depending on the condition of the materials, they may require physical repair or other preparation.

The materials then are inventoried and moved to a digitization lab, either in-house or offsite. Digitization requires scanning a master, then producing a digital object in one or more user-friendly formats. Digitized print objects are typically available in PDF format, but are increasingly available in formats for electronic book readers, as well as in a customized book-reading interface on a project Web site.

Next, during quality control, the digitization team checks the digital object carefully against the analog object. Quality control is needed because an automated technology called optical character recognition scans the alphabetical characters or letters from the analog document into digital format. During character recognition, a scanner attempts to recognize each letter or character in a word. The quality control check ensures that no mistakes occurred during the recognition process. For example, the scanner could recognize the letter "h" as a "b." Various font types, faded ink, torn and damaged pages, or simply the age of some objects can affect character recognition. After digitization, the analog objects are either retained or disposed of according to the needs of the owning institution.

Costs and Challenges

Digitization projects present numerous challenges. Even under the best of circumstances, they require significant investments of time and money. A full digitization project involves labor-hours, which often extend beyond typical projections, examination of copyright by an individual knowledgeable in that field, the use of specialized equipment, indexing to ensure that materials are searchable, and, ultimately, the long-term cost of storage and appropriate display of the resources on servers and Web sites.

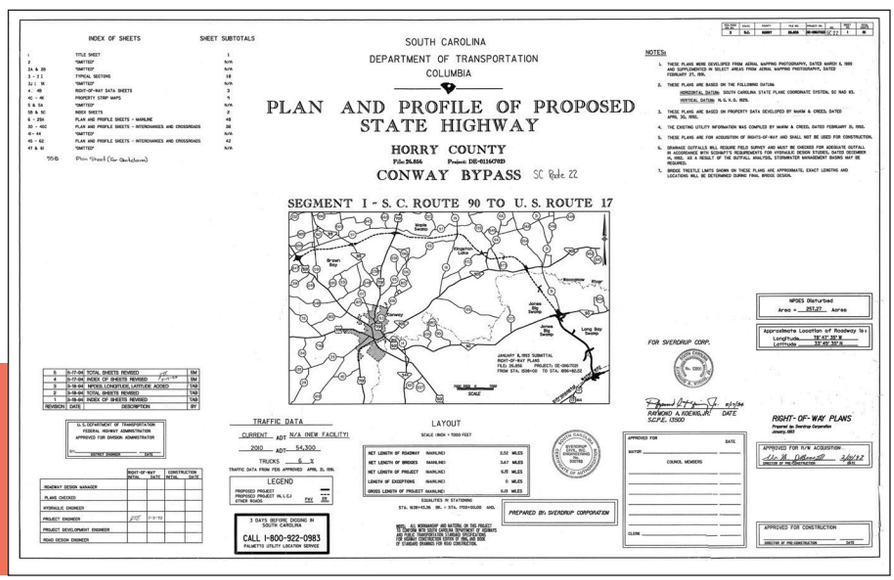
What follows are case studies of digitization projects by the South Carolina Department of Transportation (SCDOT), the Iowa Department of Transportation (Iowa DOT), Indiana's Joint Transportation Research Program, and Northwestern University. The case studies illustrate the planning, success, and lessons learned from a variety of projects.

Case Study: South Carolina

Plans Online is SCDOT's award-winning library of digitized construction plans for highways within the State's transportation system. Prior to the establishment of Plans Online, the agency's road construction plans were available only in print and located at an SCDOT facility 3 miles (4.8 kilometers) from the agency's central office in Columbia. The process to retrieve a particular plan was cumbersome and took up to several days to complete—first accessing information in a card catalog, then ordering the document from the shop facility, and finally having it delivered to the central facility.

SCDOT began in-house scanning of road plans in 1997 using an existing large-scale printer. "The cumbersome part was labeling every sheet and indexing everything. The actual scanning was the easiest part," says Mark Lorick, administrative coordinator in the Plans Storage Office at SCDOT headquarters. SCDOT used data elements such as county, route, project number, termini locations, and date of creation to index documents in Plans Online. As scanning technology became cheaper, the agency then purchased a newer large-scale printer, which it still uses today.

Early in the project, SCDOT faced a critical question of access: Would the library of plans be available to the public at no cost, or password protected with a fee? After much discussion, SCDOT officials decided to charge a nominal fee to users


INDEX OF SHEETS

SHEET SUBTOTALS

SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION
COLUMBIA

PLAN AND PROFILE OF PROPOSED STATE HIGHWAY

HORRY COUNTY

CONWAY BYPASS SC Rte 22

SEGMENT I - S. C. ROUTE 90 TO U. S. ROUTE 17

NOTES:

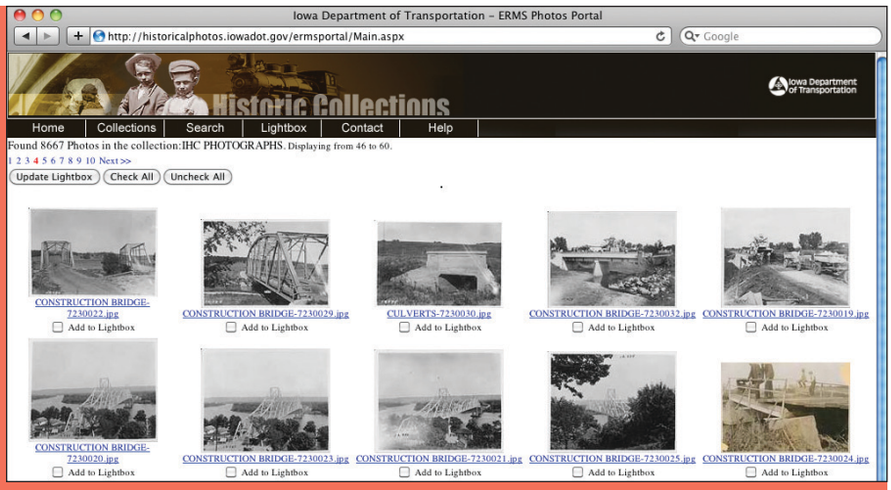
TRAFFIC DATA

LAYOUT

LEGEND

RIGHT-OF-WAY PLANS

Shown here is the title sheet from the proposed plan and profile of Conway Bypass in Horry County, SC, which was included in SCDOT's digitization project. *Source: SCDOT.*



Iowa DOT

(Above) This screen capture is from the Web portal of the Iowa DOT Historic Archives Digital Collections.

(Left) This is a screenshot from the digitized film "Highway Relocations" (U.S. 30/Lincoln Highway film production, 1960), which is part of the Iowa DOT's Historic Archives Digital Collections.

outside of State government offices. The current annual subscription price is $60, which helps to cover the cost of maintenance, operation, and improvement of the database.

SCDOT places no restriction on who may subscribe to Plans Online. The database is available to surveyors, consultants, engineers, and local officials.

Today, Plans Online contains nearly 2 million images, with plans dating from the early 20th century to current plans that were "born digital," that is, originally produced in digital format versus print format. SCDOT completed digitization of the backlog of print-based plans in 2010, and now populates Plans Online with born-digital plans for current highway projects.

The Governor of South Carolina recognized Plans Online for its efficiency improvements, and the project also was a top 10 winner of the American Association of State Highway and Transportation Officials' 2011 America's Transportation Awards in the innovative management category. (For more information, see "Best of the Best: America's Transportation Awards!" in the March/April 2012 issue of PUBLIC ROADS.)

"[Plans Online] is a tremendous help to our profession," says Joe Mitchell, professional land surveyor and former president of Mitchell Surveying. "We can now sit at a computer and access online highway right-of-way plans for the entire State. No longer do we have to travel to the different county SCDOT offices to get right-of-way information and plans."

Case Study: Iowa

The Iowa DOT, established in 1913 as the Iowa State Highway Commission, had materials in its collections dating back to its establishment. The materials were located in various Iowa DOT offices.

"The research is only valuable if people know about it and have access to it," says Hank Zaletel, former director of the Iowa DOT Library.

Beyond print materials, the Iowa DOT collections include photo negatives, maps, and 16-millimeter film. These types of nonprint materials are particularly vulnerable to loss or damage because they are more susceptible to humidity, water, and light than print materials are. In addition, the long-term storage of audio and visual materials is costly and difficult because they must be maintained in a climate-controlled facility.

The importance of nonprint materials may not be as evident to organizational leaders, who may overlook their relevance to current operations. However, Iowa DOT recognized the importance in their intrinsic historic value across a variety of disciplines and as a way to inform the public of the agency's mission and vision. For example, the DOT has used some of the digitized materials in research publications and other general interest pieces on its Web site.

In 2002 Iowa DOT established an exploration committee to look at possible

Darcy Bullock, Joint Transportation Research Program

Unprocessed technical reports published by the Joint Transportation Research Program are shown here stacked in a hallway at Purdue University.

digitization of the agency's physical collections. The committee included the agency's director of research, librarian, records manager, and office director. In 2004 a followup committee, which included experts in historic mitigation, transportation data, and public affairs, won an initial $50,000 Transportation Enhancement grant from the Federal Highway Administration to hire an archival consultant.

Marcy Flynn, an archival expert in visual materials with Silver Image Management, assisted the Iowa DOT in creating a business and digitization plan, a climate-controlled storage area, and a policy and procedures manual (an internal document) on the use of archival materials. The plan included using existing in-house equipment to digitize the photos and employing the department's existing electronic record management system. Using the two in-house systems meant an immediate cost savings for an otherwise costly process.

Efforts to digitize parts of the collection moved forward in 2007. The DOT then received another $150,000 Transportation Enhancement grant that it used to digitize the Iowa State Highway Commission's collection of 8,500 road photos.

Flynn emphasizes the importance of using quality metadata to index nonprint digitized materials. Metadata, such as information about the geographic location, date, activity, or subject of materials, makes "a big difference," she says. "A picture is worth a thousand words—but if you don't know what you're looking at, descriptive metadata can really help you access images, and identify and understand them."

Case Study: Indiana

The Joint Transportation Research Program began in March 1937 as the Joint Highway Research Project to facilitate collaboration between higher education and the transportation community to improve Indiana's highway infrastructure. The program, which reflects a long track record of collaboration between INDOT and Purdue University, most recently implemented a successful model of digitization of transportation resources.

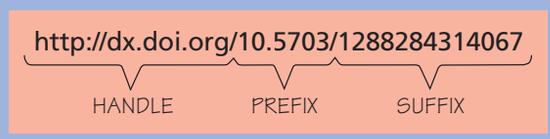
"The Joint Transportation Research Program did some great research over the past 75 years. Unfortunately, the paper reports were not very accessible," says Purdue's Bullock. "We would occasionally get requests . . . for reports from 20 or more years ago. We would have to search for the report, and attempt to make copies of some very fragile documents."

Bullock sought a solution and found it at the Purdue University Press, a unit of Purdue University Libraries, and the organization's digital online portal, Purdue e-Pubs. The Purdue University Press digitized all 1,500 of the program's historical reports in print using its in-house capabilities, which helped to keep costs down. These older reports, as well as current born-digital reports, now are published under a uniform Purdue University title page and entered into Purdue e-Pubs. A standard title page ensures easy identification of publication elements and consistency across Joint Transportation Research Program reports.

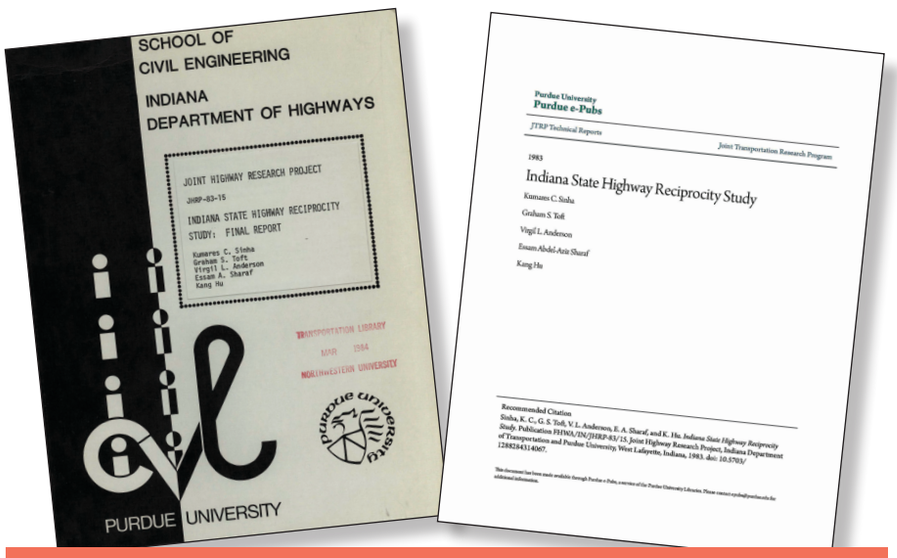
Library staff members assign a digital object identifier and add

What Is a Digital Object Identifier?

A digital object identifier (DOI) is a unique identifier of an object, typically an electronic document, but also images, audio or visual objects, and datasets. The International Organization for Standardization developed these identifiers, which now are registered through membership in the International DOI Foundation, home to more than 5,000 members with 65 million registered digital object identifier names.



A digital object identifier consists of a character string divided into two parts: a prefix and suffix. The parts are separated by a slash. The prefix is the unique identifier of the registered organization; the suffix is chosen by the organization and identifies the object linked to the digital object identifier. Name resolution, which operates like a "phonebook" by translating host names to Internet protocol (IP) addresses or vice versa, is provided through the Handle System®, a technology that manages persistent identifiers for Internet resources. The string http://dx.doi.org/ precedes the digital object identifier string and, unlike a static URL, creates a unique and persistent uniform resource identifier, or URI. The digital object identifier syntax is standardized under ANSI/NISO Z39.84-2005 (R2010), *Syntax for the Digital Object Identifier.*



The Joint Transportation Research Program and the Purdue University Press digitized this print report, *Indiana State Highway Reciprocity Study: Final Report* (left). The report then was republished with the uniform Purdue University title page (right) and entered into the university's online portal, Purdue e-Pubs. *Source: Joint Transportation Research Program.*

Roberto Sarmiento, Northwestern University Transportation Library

Printed technical reports line these shelves in Northwestern University Transportation Library's collection.

standardized metadata about the authors and subject. A digital object identifier is a unique character string used for the identification of an object. Among the metadata added to digitized reports, the program has found the digital object identifier to be one of the most valuable.

Statistics indicating the number of user hits bear out the success of placing Indiana's reports in the new digitization and publishing framework. Users have downloaded historical technical reports on the Purdue e-Pubs Web site more than 400,000 times.

"The scanned documents are now broadly accessible to anybody with Web access," says Bullock. "As an example, one 1972 report on pavement performance had [more than] 450 downloads within 6 months of being posted online."

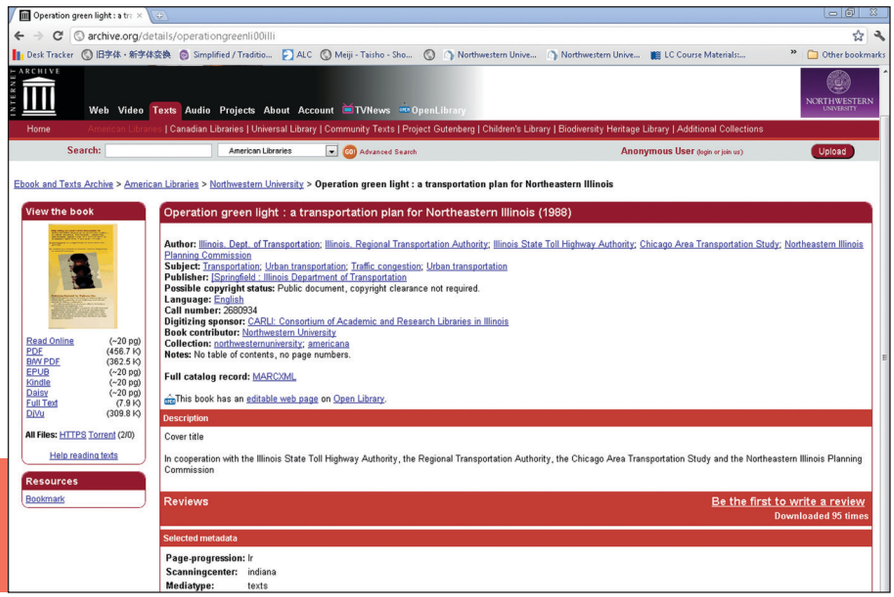
Case Study: Northwestern University

Northwestern University Transportation Library has one of the largest collections of transportation-related materials in the world. The library, which owns more than 500,000 volumes, contains materials issued by agencies at the local, State, Federal, and international levels. The library has resources from DOTs across the United States but comprehensively collects materials from the Illinois Department of Transportation (IDOT), the city of Chicago, and numerous regional transportation bodies. Twenty-four percent of the materials are unique to the library, meaning they exist only in the Northwestern collection.

Digitization at Northwestern University Transportation Library occurs via several mechanisms. The library owns its own machine for in-house digitization, typically used for digitizing fragile materials. It also outsources digitization for out-of-copyright materials. The Google Books™ Project, which began in 2010, has digitized millions of resources at Northwestern, including numerous volumes from the library itself. Also, the Consortium of Academic and Research Libraries in Illinois (CARLI) has carried out digitization workflow at Northwestern. Two projects implemented through CARLI focused on materials specific to Illinois, one on local transit, and the other on materials related to Chicago O'Hare International Airport. Both projects uncovered and digitized numerous documents from IDOT.

With such a large-scale collection like that of a major research university, Northwestern University Transportation Library's Sarmiento says, "As a manager, it's my job to make sure that our researchers have access to the best available information. We choose to digitize the best of the best. We select the materials that give us the best bang for our buck. We want to digitize the materials with the highest return on investment, not just for our patrons, but also to prove [the digitization's] worth to our management and institution."

Access to digitized materials is a high priority at Northwestern. The university shares metadata across numerous portals that point



The portal of archive.org features digitized documents from IDOT and other agencies.

Costs Associated with Digitization

Although the cost of digitization is difficult to estimate because it varies greatly among institutions, the following are some expenses typically incurred beyond a basic cost per page of digitization:

- Labor
- Overhead
- Materials preparation and repair
- Postage
- Metadata and description
- Quality control
- Server storage

to the digital objects. For example, items from the CARLI digitization projects are discoverable at the Internet Archive, the standard portal for CARLI materials; NUcat, the Northwestern University Libraries catalog; OCLC WorldCat, a global network of library content and services; and the Transportation Research International Documentation (TRID) database at the Transportation Research Board.

David E. Kosnik, Ph.D., P.E., research engineer at the Northwestern University Infrastructure Technology Institute, points to digitized documents being used during field work involving structural health monitoring of IDOT's steel and concrete bridges. "To get the data we need to understand performance and deterioration of real-world structures, we install sensors on inservice bridges, buildings, and tunnels—facilities that are typically exposed to the elements," Kosnik says. "We often consult reports and other technical documents and drawings while in the field as we determine the best instrumentation and monitoring plan for a given facility. The portability and searchability of digitized documents makes this process easier and prevents damage to physical documents from field hazards such as rain, wind, debris, grease, and muddy boots."

Best Practices

Digitization projects require copious amounts of planning time that can vary greatly by project. Selection, preparation, delivery, and creation of a metadata schema (a set of predefined elements) are particularly time consuming, especially for an institution undertaking a digitization project for the first time. Assigning as much metadata as possible within the budget is critical. To save time and costs, using in-house equipment and systems is also beneficial. Executing part or all of a project in-house could help achieve significant cost savings versus outsourcing the entire project.

To save additional time and money, team leaders of digitization projects should exercise caution when identifying and selecting materials. A collection should have a coherent theme, appeal to a defined audience, and have a well-defined end use. In addition, taking steps to avoid duplication of work already done by other digitization projects can save significant amounts of time and money.

Quality control is also important. For each resource, the digitization team should examine the copyright carefully before digitization. While Federal guidelines on digitization are available from sites such as www.copyright.gov/laws, laws governing documents created by and for State, local, and municipal agencies differ from Federal guidelines. When materials lack an office from which to obtain copyright clearance, the organization should consult its legal counsel. In addition, digitization teams should run quality control checks on digitized objects before releasing the materials to the public. Missing pages, bad imaging, and corrupt files could compromise a project's quality and validity in the public's eye.

Lastly, an organization should plan for a public relations strategy at the start of a major digitization project. Communicating with the public will introduce the digitized materials to potential users and also help to prove the worth of the project to the funding organization, managers, and other stakeholders.

While print and other analog resources present challenges of access to localization, restriction, and portability, various innovations in digitization can help agencies overcome these limitations. Many State DOTs, often in conjunction with universities and institutions well-versed in digitization, have digitized large collections of print materials. These efforts mean improved access to transportation-related information for transportation researchers and practitioners, and the broader research community.

Paul R. Burley is the technical services librarian at the Northwestern University Transportation Library in Evanston, IL. He received his master of information science degree from the University of Michigan in 2001. His areas of interest are metadata production, cataloging workflow, and authority control.

For more information, visit www.library.northwestern.edu/transportation or contact Paul Burley at 847-491-5274 or p-burley@northwestern.edu.

Daniel R. Marron, P.E., chief research engineer at the Northwestern University Infrastructure Technology Institute, is using digitized resources as part of field research in structural health monitoring of bridge components.

David E. Kosnik, Northwestern University

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 (USDOT) sources unless otherwise indicated. Your suggestions and input are welcome. Let's meet along the road.

Technical News

Caltrans Streamlines Electronic Bidding Process

The California Department of Transportation (Caltrans) has begun a pilot program to accept contractor bids through an online electronic bidding system. For contractors, the electronic system simplifies bidding on projects. Previously, contractor bids had to be delivered by hand to Caltrans district offices across the State, depending on where the job was to be built.

Caltrans awards more than 600 contracts annually and receives as many as 5,000 bids for these projects. With the new pilot program, contractors now have the option of submitting their bids online at www.bidx.com. At present, departments of transportation in 37 States accept bids through the site.

Caltrans expects a gradual transition from the existing system to the electronic bidding pilot program, with both methods of bid submittal available as contractors decide which works best for them. Recently, Caltrans trained approximately 100 contractors across the State on how to use the Web-based interface to submit electronic bids.

Caltrans

Public Information and Information Exchange

Administrator Mendez Visits Missouri for Redesignation of U.S. 71 as I–49

Federal Highway Administrator Victor Mendez joined Federal, State, and local officials for the redesignation of 180 miles (290 kilometers) of U.S. 71, now known as I–49, near Joplin, MO. Over the last two decades, the Missouri Department of Transportation (MoDOT) rebuilt the highway to interstate standards to increase traffic capacity in the region and improve Missouri's economic competitiveness.

Construction on the first segment of the new I–49 from I–44 south to Pineville, near the Arkansas State line, began in 1993. Work on the second segment—from I–44 north to Kansas City—began in 2009. Improvements included upgrades to numerous interchanges and overpasses and the elimination of at-grade rail crossings along the route, which will improve safety for the thousands of motorists who use the route daily. MoDOT estimates that 16,000 drivers use the highway each day, a figure the agency expects will nearly double over the next 20 years.

Once a 5-mile (8-kilometer)-long segment of the old U.S. 71 known as the Bella Vista bypass is rebuilt to interstate standards, Missouri's stretch of I–49 will be complete. Arkansas and Louisiana currently are working to rebuild key segments of the route through their States. Once completed, I–49 will stretch more than 1,600 miles (2,575 kilometers) and significantly improve freight movement through the central United States from Canada to the Gulf of Mexico.

Administrator Mendez greets Missouri Senator Roy Blunt, Jr., at the redesignation of U.S. 71 as I–49.

USDOT Ranks #9 in Best Places to Work

USDOT moved into the top 10 in the 2012 Best Places to Work rankings for large government agencies, according to the nonprofit Partnership for Public Service. The department also was the most improved large agency based on the change in performance between 2011 and 2012. Within USDOT, the Federal Highway Administration (FHWA) and Federal Railroad Administration achieved rankings in the top 10 and top 20, respectively, for agency subcomponents.

Since 2009, USDOT has climbed 11 percentage points in the Best Places to Work rankings.

For more information about the Partnership for Public Service and the Best Places to Work in the Federal Government® rankings, visit www.bestplacestowork.org/BPTW/about.

AASHTO Offers Strategies to Communicate Funding Issues

Transportation agencies sometimes face an uphill battle gaining broad public support for increased investment in infrastructure projects. To help, the American Association of State Highway and Transportation Officials (AASHTO) released a peer exchange report titled *Communicating Transportation Funding Issues* that offers practical approaches to making the case for transportation investments to the public and key decisionmakers.

Twenty-four senior executives from State departments of transportation (DOTs) participated in the peer exchange in Irvine, CA, in June 2012. The report focuses on four key elements of communication: audience identification, market research, message design, and message delivery. The AASHTO Center for Excellence in Project Finance and FHWA sponsored the peer exchange and the resulting report.

The report includes best practices from almost a dozen State DOTs that have communicated effectively about complex issues associated with finance, funding, planning, and project selection. Case studies highlight successful communication techniques that improved the public's understanding of transportation investment needs, funding options, and program management and implementation.

The final report is available at http://downloads.transportation.org/AASHTO_Peer_Exchange-Communicating_Funding_Issues.pdf.

AASHTO

Iowa Releases Study on School Bus Safety

The Iowa Departments of Transportation and Education recently released a report, *School Bus Safety Study—Kadyn's Law*, to the Iowa General Assembly. Researchers at Iowa State University and the University of Iowa have evaluated school bus safety measures and found that buses are one of the safest forms of transportation available. However, vehicles illegally passing stopped school buses remain a significant concern.

The study explored three specific safety elements. First, researchers considered the use of cameras mounted on school buses to aid in enforcement of stop-arm violations. Second, they examined the feasibility of requiring children to be picked up and dropped off on the side of the road on which their home is located.

On March 16, 2012, the Iowa legislature passed a bill that required a study of school bus safety. Referred to as "Kadyn's Law," the bill honors the memory of Kadyn Halverson, a 7-year-old killed by a driver who failed to stop for a stopped school bus with its lights flashing and stop arm extended. *Photo: Neal Hawkins, Center for Transportation Research and Education.*

Third, the report discussed the inclusion of school bus safety as a priority in driver training.

The Iowa DOT and FHWA cosponsored the study. The Iowa Department of Public Safety also played a key role by sharing valuable insights into enforcement and educational aspects.

The report is available at www.iowadot.gov/schoolbus/pdf/Finalreport-Kadynslaw.pdf.

Iowa DOT

PBIC Launches Series of White Papers

The Pedestrian and Bicycle Information Center (PBIC) recently announced the creation of a series of white papers to expand access to the latest pedestrian- and bicycle-related research, resources, and tools.

The white papers will provide a broad array of information about some of the most commonly requested topics of interest among engineers, public health officials, planners, and advocates. PBIC already has completed the first two papers: "An Overview of Automated Enforcement Systems and Their Potential for Improving Pedestrian and Bicyclist Safety" and "Using Health Impact Assessments to Evaluate Bicycle and Pedestrian Plans." Future topics include high-visibility crosswalks, road diets, and cycle tracks.

To read the white papers and other PBIC publications, visit www.walkinginfo.org/library.

PBIC

VDOT Report Focuses on Active Traffic Management

The Virginia Center for Transportation Innovation and Research recently released a report that presents guidelines for incorporating active traffic management into the planning process for investments in highway capacity. Tactics for active traffic management include use of variable speed limits, queue warning systems, and dynamic ramp metering.

Sponsored by the Virginia Department of Transportation (VDOT), the report, *Planning for Active Traffic Management in Virginia: International Best Practices and Implementation Strategies* (VCTIR 13-R1), offers four sets of guidelines. The first identifies infrastructure and operational conditions, such as sensor placement and queuing behavior, required for active traffic management at a given site. The second set of guidelines relates to methods for sketch planning analysis, which is used to estimate the operational and safety benefits of applying a particular technique at a site. The third set covers detailed simulation analyses, while the fourth concerns continued monitoring of sites where strategies for active traffic management have been deployed.

The report also provides a framework for incorporating these strategies into the regional planning process. The framework is illustrated with a hypothetical case study of variable speed limits implemented on I–66 in Virginia.

In addition, the report compares active traffic management with other techniques to manage capacity. For example, the appendix illustrates how to compute a benefit-cost ratio in which costs might include capital and operations expenditures for active traffic

management, and benefits might include monetized values of avoided crash costs and vehicle-hours of delay.

For more information or to download the report, visit www.virginiadot.org/vtrc/main/online_reports/pdf/13-r1.pdf.

VDOT

NYC Highlights Benefits of Pedestrian-Friendly Projects

Every year the New York City Department of Transportation (NYCDOT) produces an annual progress report known as the *Sustainable Streets Index* that takes stock of transportation trends and evaluates the city's various transportation initiatives. In addition to recording overall trends, the most recent *Sustainable Streets Index*, released in August 2012, assesses projects to improve safety for pedestrians and bicyclists, enhance transit mobility and public spaces, and reduce congestion. All of the projects highlighted were implemented in 2010.

The report suggests that relatively inexpensive projects to improve pedestrian and bicyclist safety can have a range of benefits, such as lowering injury crashes for pedestrians and motor vehicle occupants, decreasing speeding, and increasing the availability of public and green spaces. Others include increasing bicycle usage and providing economic benefits for merchants located in the vicinity of the improvements.

For the "Broadway: Union Square" project, for example, NYCDOT made various pedestrian-friendly improvements including installing pedestrian safety islands, a protected bicycle lane (separated from vehicle traffic by on-street parking), and a pedestrian plaza. Some of the project's results include a 65-percent reduction in crashes involving motor vehicles and a 26-percent reduction in crashes involving injuries, as well as a 16-percent decrease in the number of vehicles traveling over the speed limit on Broadway. The project also increased bicycle ridership on Broadway, up 18 percent on weekdays and 49 percent on weekends. Many storeowners reported that the new public spaces helped their businesses.

For more information or to download the report, visit www.nyc.gov/html/dot/html/about/ssi.shtml.

NYCDOT

A new series of commemorative stamps honors Lady Bird Johnson's efforts to beautify highway rights-of-way. *Photos: USPS.*

USPS Stamp Set Celebrates Lady Bird Johnson

The United States Postal Service (USPS) recently released a set of six stamps honoring Lady Bird Johnson and her dedication to beautifying the Nation's streets, highways, parks, and cities. As First Lady, Mrs. Johnson championed the Highway Beautification Act of 1965, often referred to as "Lady Bird's Bill." She was a powerful voice in the movement to protect native plants and maintain a sustainable and beautiful environment.

Mrs. Johnson remained committed to highway beautification after leaving the White House, supporting legislation allocating Federal funds for landscaping projects using native vegetation along the Nation's highways. The six stamps include a reproduction of the official White House portrait of the First Lady and adaptations of five stamps originally released in the 1960s for President and Mrs. Johnson's beautification campaign.

For more information, visit http://about.usps.com/news/national-releases/2012/pr12_141.htm.

USPS

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, Paula Magoulas, via email (paula.magoulas@dot.gov), telephone (202–493–3398), or mail (Paula Magoulas, 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.

Internet Watch

by Kate Sullivan

A New Home for Transportation Software

AASHTOWare®—a suite of software for designing and managing infrastructure projects—has helped transportation professionals monitor costs, schedules, inventories, inspections, safety, and performance for more than 25 years. Authorized by the board of directors of the American Association of State Highway and Transportation Officials (AASHTO) in 1986, the AASHTOWare technical service program provided centralized support and maintenance of legacy mainframe software used by multiple State departments of transportation (DOTs).

AASHTO bills the software as "designed by transportation professionals for transportation professionals." Developed and updated continually by experts from across the country, the software is used by transportation employees in all 50 States; Washington, DC; Puerto Rico; and Canada.

By 2011, both the software and the Web site promoting it, which launched in 2000, were ready for revamping.

Stronger Brand Identity

One of the major objectives of the Web site redesign was a better strategy for branding identity. The existing products—with names like "DARWin" and "Opis"—did not describe the software's purpose, and were hard for users to identify, search for, and understand. The corresponding icons were equally confusing.

The process of developing new names and logos for each product took a year, and a group of subject matter experts from State DOTs oversaw each product's revisions. A marketing consultant traveled the country, meeting with representatives from the State DOTs, to explain the updates and gain buy-in from AASHTO members on the changes.

"Our major objective was to streamline and improve the online experience for users," says Jan Edwards, AASHTOWare project director. "Users can find what they need faster and easier."

Under the new branding, the product name "DARWin" became "Pavement ME-Design" and "Opis" became "Bridge Design," for example, making the user's choice of products simple and straightforward. The site's home page now features prominent buttons for each of the software's five major application areas:

- AASHTOWare Project, a suite of products covering the entire life cycle of contract management for construction projects
- AASHTOWare Bridges, software tools for bridge design, analysis, load rating, and management
- AASHTOWare Pavement, an application for state-of-the-art mechanistic and empirical pavement design and analysis
- AASHTOWare Safety, analytical tools and data for improving highway safety
- AASHTOWare Right of Way, software designed to streamline relocation assistance

The rebranded AASHTOWare software line and its Web site launched in November 2012.

Simplified Navigation

Another key goal in the redesign was simplifying the navigation and making it more accessible to a variety of potential users. "Our existing system was difficult for nonengineers to understand," Edwards says. "Our strategy was to simplify."

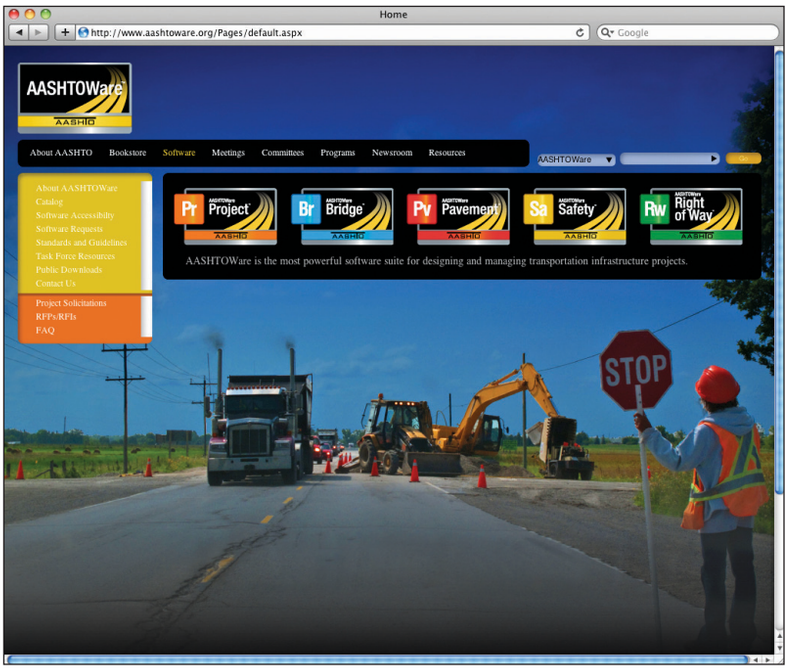
In particular, Edwards notes that the new Web site replaces jargon with copy written in layman's terms, and the revamped design presents the software products in a fresh, cohesive, color-coded layout that makes navigation simpler.

"Visitors now can get a better understanding of AASHTOWare and its many products," she adds. "Overall, the Web site clarifies what we have, how it works, and how to order."

The site also provides key product information, including fees, options, hardware and software requirements, and required forms. The left navigation on the home page features a menu of options for information about and access to AASHTOWare, including "Catalog," "Software Accessibility," "Standards and Guidelines," "Task Force Resources," and "Public Downloads." In addition, users can access links to "Project Solicitations," "RFPs/RFIs"—requests for proposals/requests for information—or "FAQ," for frequently asked questions.

AASHTOWare's revamped Web site is accessible at www.aashtoware.org/Pages/default.aspx.

Kate Sullivan is a contributing editor for PUBLIC ROADS.



Training Update

NATIONAL HIGHWAY INSTITUTE

by Candice Jackson and Kate Sullivan

Bridge Inspection Goes Virtual

The Nation's bridge infrastructure depends heavily on the work of inspectors to ensure safety and performance. A high level of expertise is required to ensure that bridges meet an exacting set of standards and are safe for public use. Inspectors are therefore federally mandated to undergo comprehensive training to lead bridge inspection teams or to become program managers. This demand for high-quality training is the reason the National Highway Institute (NHI) offers training course 130055 Safety Inspection of In-Service Bridges.

Updated in 2012, the training is based on the latest edition of the Federal Highway Administration's (FHWA) *Bridge Inspector's Reference Manual*, which provides the most current information on the safety inspection of in-service highway bridges. Because field experience is such a valuable component of the training, NHI extended the field trip requirement to 2 bridges instead of 1, as part of the update. However, hosting agencies sometimes find it challenging to identify individual bridges with an instructive combination of deficiencies to highlight for participants. Inclement weather, travel and logistical challenges, and safety concerns also pose barriers that sometimes impede successful field trips.

To overcome these challenges, NHI now offers a 3-D, computer-based training alternative to traditional field inspection activities: virtual bridge inspection.

Developing the Training Environment

The virtual inspection exposes training participants to 30 bridge conditions and defects that reflect a wide variety of problems encountered in the field during real-world inspections.

The project team considered various forms of modeling and ultimately selected a versatile, affordable, multiplatform software program used for video game development. This solution offered the potential to create a computer-based training environment that uses high-quality graphics and is easy to navigate. The team also deemed critical two other features: that the program not require connection to the Internet or a network, since training often is conducted at remote sites with no Internet access, and that it be intuitive to use, to minimize class time spent bringing participants up to speed on how to use it.

Next, the development team created two virtual bridges: one four-span steel bridge that crosses over a divided highway and one single-span concrete bridge that spans a waterway. Each bridge has 15 checkpoints that represent defects, thereby exposing the participants to a total of 30 typical defects. The program uses an avatar—or virtual representation of the user—and is designed to offer a 3-D, first-person perspective.

"The software was created to help participants feel like they are physically present in the inspection setting," explains Meredith Perkins, senior instructional system designer at Sevatec, Inc., a contractor for NHI. "The environment is very realistic, with clouds and shadows, an airplane flying overhead, and a stream that moves and babbles."

Conducting Virtual Inspections

Before participants are allowed onto the virtual bridge, they must select safety gear and put it on their avatars, as well as set up the proper traffic safety features. Each participant is provided with 14 tools commonly used by bridge inspectors, including a hammer, grinder, tape measure, flashlight, under-bridge inspection truck, chain drag, and spray paint. The tools were designed to be as realistic as possible.

Participants work in teams of two and complete the same bridge inspection forms they would in the field. They can review previous reports and the *Bridge Inspector's Reference Manual*, and view real-life photos of the defects. Once participants have finished their inspections, the software program presents a checklist to make sure they have addressed every problem.

"When we use actual bridges, we're 'lucky' if we can find one with five or six defects," says Douglas Blades, a bridge engineer in FHWA's Office of Bridge Technology. "You'd rarely find 15 defects on a real bridge; this way, we can train inspectors in the entire range of possible defects at one time."

To support the training, NHI created a mobile computing lab complete with 15 laptops loaded with gaming-quality graphics cards and high-resolution, 1,600- by 900-pixel screens. Thanks to this virtual inspection option, agencies now have additional flexibility when scheduling a session of NHI course 130055, which could be handy during inclement weather or when logistical issues make field trips problematic.

For course details and to schedule a session, visit NHI's Web site at www.nhi.fhwa.dot.gov.

Candice Jackson is a contractor for NHI.

Kate Sullivan is a contributing editor for PUBLIC ROADS.

Meredith Perkins, Sevatec, Inc.

An NHI instructor oversees participants using the virtual bridge inspection technology in the classroom. The video projection on the screen shows an inspector's avatar.

Communication Product Updates

Compiled by Lisa Jackson 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).

Performance Testing for Superpave and Structural Validation (Report)
Publication Number: FHWA-HRT-11-045

This report shares findings from research conducted under two transportation pooled fund projects: *Full-Scale Accelerated Performance Testing for Superpave and Structural Validation* and *Accelerated Pavement Testing of Crumb Rubber Modified Asphalt Pavements.* Researchers identified specification tests that perform better than current SUperior PERforming Asphalt PAVEment (Superpave®) tests at determining expected fatigue cracking and rutting performance. Full-scale accelerated pavement testing and laboratory characterization tests on mixtures and binders provided the basis for recommendations.

The researchers evaluated the tests based on their ability to discern resistance to fatigue cracking and rutting. Using full-scale performance and laboratory tests, the researchers demonstrated that asphalt modified with crumb rubber could significantly slow or stop the growth of fatigue cracks in a composite asphalt pavement structure. A hybrid technique to modify asphalt with a combination of crumb rubber and conventional polymers, called terminally blended crumb rubber, exhibited good fatigue cracking resistance relative to the control binder. Also, the simple addition of polyester fibers to asphalt mix provided high resistance to fatigue cracking without the use of polymer modification.

The researchers also quantified the capabilities of the National Cooperative Highway Research Program's methodologies for mechanistic-empirical pavement design and analysis to predict rutting and fatigue cracking of modified asphalts.

The report is available to download at www.fhwa.dot.gov/publications/research/infrastructure/pavements/11045/index.cfm. Printed copies are available from the PDC.

Federal Highway Administration 100-Year Coating Study (TechBrief)
Publication Number: FHWA-HRT-12-045

This TechBrief, which summarizes the report *Federal Highway Administration 100-Year Coating Study* (FHWA-HRT-12-044), presents the results and major findings from a performance evaluation of eight selected coating systems based on experimental data from laboratory and field testing.

The study began in August 2009 and focused on searching for durable coating systems with the potential to provide 100 years of virtually maintenance-free service life for steel bridge structures at costs comparable to existing coatings. Researchers selected three three-coat systems (two of which served as controls for the study), four two-coat systems, and one single-coat system of high-ratio calcium sulfonate alkyd. Then they evaluated all the coating systems under accelerated laboratory testing as well as outdoor exposure under natural weathering with and without salt spray in McLean, VA, and at the Golden Gate Bridge in San Francisco, CA.

The study found that none of the selected coating systems, including the two three-coat control systems,

will provide maintenance-free corrosion protection for 100 years. Based on performance records in earlier FHWA studies, the researchers had selected two three-coat control systems that performed better than other test coating systems in every category. They selected five test coating systems hypothesized to provide superior performance compared to commercially available products, but these did not deliver desirable performance exceeding the three best coating systems. Further, the researchers observed unexpected premature failure of two of the two-coat systems. Three of the tested coating systems performed satisfactorily in some categories but poorly in others compared to the best performers.

This TechBrief is available to download at www.fhwa.dot.gov/publications/research/infrastructure/structures/bridge/12045/index.cfm. Printed copies are available from the PDC.

Casual Carpooling Scan Report (Report)
Publication Number: FHWA-HRT-12-053

This report discusses the results of a study on casual carpooling, also known as dynamic ridesharing, conducted for FHWA's Exploratory Advanced Research (EAR) Program. The study involved a scan team of transportation professionals, academics, and entrepreneurs who visited informal carpool lines (also known as slug lines or casual carpool lines) in San Francisco, CA; Washington, DC; and Houston, TX, in November and December 2010.

The team observed "slugs" (riders who typically assemble at bus stops and park-and-ride lots throughout a metro area to catch a ride to work) and compared practices among locations. They also met with private ride-match providers, regional planners, carpool participants, and transportation planners and engineers. Scan team members reported on what they learned at the casual carpooling sites and identified gaps in the data and research.

The team found that casual carpooling participants are motivated by saving time and money. Passengers tend to feel safer when there is a second occupant in the vehicle, but a second passenger is not always required for passengers to feel safe getting into a car. Infrastructure, including barrier-separated reversible high-occupancy vehicle (HOV) lanes, park-and-ride lots, and direct access to HOV lanes from parking areas, can play an important role in creating conditions conducive to casual carpooling. Transit and casual carpooling are complementary modes of transportation, as slugs tend to use transit as a backup mode. The team also noted that it is difficult to say what role technology might play in bringing casual carpooling to new locations.

This report is available to download at www.fhwa.dot.gov/advancedresearch/pubs/12053/index.cfm. *Appendix B to the Casual Carpooling Scan Report* (FHWA-HRT-13-023), which includes the observations of the individual members of the scan team at each slug line, is available to download at www.fhwa.dot.gov/advancedresearch/pubs/13023/index.cfm.

Share Your Highway Safety Expertise!

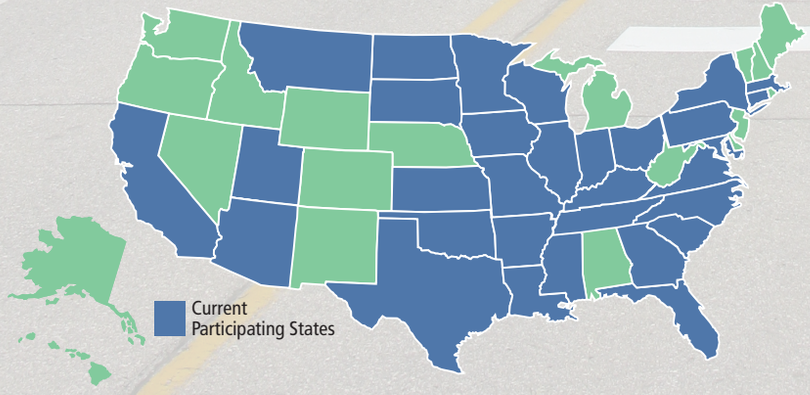
Join the Technical Activity Committee for Evaluations of Low Cost Safety Improvements Pooled Fund Study.

The next generation of this pooled fund study, "The Development of Crash Modification Factors," started in December 2012. Now is your chance to collaborate with your fellow transportation experts from across the country.

With just a $5,000 annual contribution, your organization can help:

- Set the research agenda to generate information critical to your State's safety efforts.
- Add to the knowledge base with your State's experiences and perspectives.
- Bring to light new safety strategies or issues facing the Nation's roadways.
- Increase the accuracy of study results by contributing your State's data.
- Engage others in discussing issues facing your State and how to overcome challenges.

For more information, visit
www.fhwa.dot.gov/research/tfhrc/projects/safety/comprehensive/elcsi/index.cfm.
To join the committee, contact Roya Amjadi at 202–493–3383 or roya.amjadi@dot.gov.



U.S. Department of Transportation
Federal Highway Administration

Photo: Institute for Transportation at Iowa State University

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. 033-3735
USPS NO. 516-690

FHWA-HRT-13-004
HRTM-20/5-13(5M200)E