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U.S. Department of Transportation
Federal Highway Administration

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

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Front cover—Construction workers complete survey staking for an interstate on-ramp at I–96 and Walker Avenue, just north of Grand Rapids, MI. The project, a partnership between the Michigan Department of Transportation (MDOT) and the city of Walker, broke ground in April 2006 and was completed in November of that year. *Photo: John Ryynanen, Michigan LTAP, Michigan Tech Transportation Institute.*

Back cover—Excavators load sand for use as sub-base material on the M–26 realignment project between South Range and Trimountain, MI. MDOT completed the project in 2006, working in cooperation with the village of South Range. *Photo: Martin Rajala, MDOT.*

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Guest Editorial

Meeting a Daunting Challenge

It's no secret that the Nation's system of roads and bridges is aging. Much of the system has exceeded its design life, some is in poor condition, and the backlog of needed work is significant. The current economic situation has resulted in major budget shortfalls at all levels. On top of that, drops in travel have resulted in a corresponding loss of revenue from fuel taxes to fund the investments needed. Some have called this a perfect storm.

But how often, especially in times of crisis, has the highway industry risen to a challenge and pulled together the hard work and creativity necessary to overcome adversity? Whether the problem is a bridge knocked down by a barge in Oklahoma, a melted freeway entrance ramp in northern California, or pavement washed away by a hurricane in Florida, the highway community has a long tradition of successfully responding to difficult situations. The difference here, of course, is the magnitude of the situation.

To help the United States meet the current infrastructure problems, many innovative approaches are available and ready to deploy. More are being developed all the time. These proven innovations can produce better quality, longer lasting roadways and bridges. And they can help highway agencies complete construction projects faster, more safely, with less impact on the driving public and, in many cases, at a lower cost.

But the true challenge is not simply coming up with such innovations; rather, it's making the decision—as individuals and organizations—to use them. The key is resolving to drop the old way, the "way it's always been done," in order to move on to alternative approaches. Too often, it takes years or even decades to adopt as standard practice innovations that can benefit road users. And that timeframe is no longer acceptable, especially in the face of the current financial situation.

To speed up the deployment process, in 2005 the U.S. Congress established within the Federal Highway Administration (FHWA) a pilot program called Highways for LIFE. Specifically, Highways for LIFE provides incentives to encourage highway agencies to use innovations and customer-focused performance goals to build highways and bridges. The program uses proven marketing approaches and dedicated teams to demonstrate how to deploy innovations faster and more effectively.

FHWA created a training program to teach these techniques to the highway community so they can champion new approaches and accelerate the deployment of innovations. Highways for LIFE is also helping private industry move prototypes of promising innovations into the marketplace where they can benefit the traveling public.

An article in this issue of PUBLIC ROADS, "A Mix of Innovations Succeeds in Minnesota," describes how the Minnesota Department of Transportation, an early recipient of Highways for LIFE funding, successfully applied several innovative approaches on a recent highway project. Also, see page 44 to learn more about the new National Highway Institute course Leap Not Creep: Accelerating Innovation Implementation.

Thus, this perfect storm affords the Nation the perfect opportunity, not simply to *find* better ways of building highways, but to change how the industry responds when those better ways are offered. The question that needs to be answered is, How will the highway community meet this daunting challenge?

Byron Lord
Program Coordinator
Highways for LIFE
Federal Highway Administration

FHWA engineers are using geophysical investigations to characterize subsurface conditions.

Peering Into the Unknown

by Amit Armstrong, Roger Surdahl, and H. Gabriella Armstrong

(Above) Geotechnical drilling, as these workers are doing as part of a rehabilitation project on the Going-to-the-Sun Road in Glacier National Park in Montana, is one of several methods highway agencies can use to characterize subsurface conditions.

Transportation engineers often need to learn about conditions beneath the surface when they plan to rehabilitate existing roads or build new ones. In Hawaii, for example, subsurface lava tubes could collapse and bring a roadway down with them, or in Colorado, abandoned lead mines could similarly undermine construction. Complicating matters, test borings and excavations themselves can be intrusive, especially in environmentally sensitive areas.

As the Federal Highway Administration (FHWA) strives to uphold its commitment to environmental stewardship, the agency increasingly is using geophysical imaging and geophysical testing methods for site characterization and geotechnical investigations before and during highway construction. These methods represent environmentally sensitive options for collecting timely information that can influence design quality and roadway performance. Nondestructive geophysical methods enable engineers to peer into the unknown and gain detailed knowledge of highly variable subsurface conditions to improve safety during construction and mitigate project risks and costs associated with "change of conditions" claims, when contractors encounter different and more expensive subsurface conditions than specified in their contracts.

"Geophysics involves the use of nondestructive methods to determine the nature, characteristics, and extent of natural or manmade materials below the ground's surface or within manmade structures," says David Lofgren, engineering geologist with FHWA's Western Federal Lands Highway Division (WFLHD). "Geophysical testing is based on the ability of certain types and frequencies of manmade energy, such as radio frequency, seismic vibration, and acoustic and electrical energy, to penetrate the ground and certain manmade materials such as concrete, and to measure the change in behavior of the energy that occurs when it passes through, or is reflected or refracted by, those materials."

FHWA's Office of Federal Lands Highway (FLH) has been deploying a number of geophysical imaging and other geophysical methods in innovative ways. When off-the-shelf solutions have not been effective, FLH engineers have designed and developed new approaches to overcome engineering challenges.

In 2003, the FLH publication *Application of Geophysical Methods to Highway Related Problems* (FHWA-IF-04-021) shared with highway engineers a basic knowledge of geophysics and methods for enhancing geotechnical investigations. The document provides a broad range of practical methods for evaluating the physical properties of soil and rock, such as seismic methods used to estimate the depth to bedrock or locate underground voids. Below are highlights of selected geophysical investigation techniques and successful applications thereof on recent FLH projects.

Types of Geophysical Methods

Many applications in highway engineering could benefit from the use of geophysical methods, including evaluation of the thickness and condition of pavement structures; detection of subsurface voids (gaps), caves, and abandoned mine openings; and determination of the location and extent of voids in reinforced concrete structures such as bridge piers and foundations.

Two of the more familiar types of nondestructive geophysical testing are seismic refraction and reflection, which are based on measurements of velocity changes that occur when manmade acoustic (seismic) waves encounter materials of differing material properties below the ground's surface. Another technique is ground penetrating radar (GPR), which utilizes the reflection of radiowave to microwave electromagnetic frequencies in materials of varying dielectric permittivity (and low electrical conductivity) to map natural and manmade subsurface features. Yet another technique is electrical resistivity, which uses an electrical current sent through the ground to determine subsurface water conditions; evaluate aquifers, wells, and plumes; detect voids; and evaluate environmental aspects of landfills.

Approaches to employing geophysical methods vary widely depending on the experience and knowledge of the operators and agencies using them. In the past, some engineers were reluctant to employ geophysical techniques on

Application of Geophysical Methods To Highway Engineering Problems

Engineering Problem	Application	Geophysical/Nondestructive Solutions
Bridge System Substructure	Unknown Depth of Foundations	Sonic Echo/Impulse Response, Bending Wave, Ultraseismic, Seismic Wave Reflection, Transient Force Vibration, Parallel Seismic, Induction Field, Borehole Logging, Dynamic Foundation Response, Borehole Radar, Borehole Seismic
	Integrity Testing of Foundations and Structures	Crosshole Sonic Logging (CSL), CSL Tomography, Gamma-Gamma Density Logging, Single Hole Sonic Logging, Sonic Echo/Impulse Response, Ultraseismic Profiling, Ultrasonic Pulse Velocity, Impact Echo, Ground Penetrating Radar (GPR), Spectral Analysis of Surface Waves, Acoustic Emissions, Radiography
	Rebar Quality and Bonding	Half-Cell Potential, Linear Polarization Resistance, Galvanostatic Pulse Technique, Electrochemical Noise, Acoustic Emissions, Magnetic Field Disturbance
	Foundation Scour	Time Domain Reflectometry, Parallel Seismic, GPR, Continuous Seismic Reflection Profiling, Fathometer
Bridge System Superstructure	Bridge Deck Stability New Decks Baseline Assessment Existing Decks	Vibration Monitoring, GPR, Electromagnetic, Impact Echo, Spectral Analysis of Surface Waves and Ultrasonic Surface Waves Methods, Half-Cell Corrosion Potential Mapping, Infrared Thermography
Pavements	QA/QC of New Pavements Existing Pavements Transportation/ Geotechnical Methods	GPR, Impact Echo, Spectral Analysis of Surface Waves, Ultrasonic Surface Wave, Multichannel Analysis of Surface Waves
Roadway Subsidence	Mapping Voids, Sinkholes, Abandoned Mines, Other Cavities	Gravity, GPR, Resistivity, Seismic Refraction, Seismic Reflection, Rayleigh Waves Recorded With Common Offset Array, Cross-Borehole Seismic Tomography
	Roadbed Clay Problems	Conductivity Measurements, Resistivity Measurements, Time Domain Electromagnetic Soundings, Induced Polarization
Subsurface Characterization	Mapping Bedrock, Lithologies, Sand and Gravel Deposits, Groundwater Surface, and Flow	GPR, Seismic Refraction, Compressional and Shear Wave Reflection, Resistivity, Time Domain Electromagnetic, Conductivity Measurements, Spectral Analysis of Surface Waves, Gravity, Very Low Frequency Electromagnetic, Borehole Televiewer, Induced Polarization, Borehole Gamma and HydroPhysical Logging, Nuclear Magnetic Resonance, Self Potential, Electroseismic
	Determining Engineering Properties and Rippability of Soil and Rock	Seismic Refraction, Nuclear Magnetic Resonance, GPR, Spectral Analysis of Surface Waves, Suspension Logging, Full Waveform Sonic Logging, Crosshole Shear
	Utility Locator, Detecting Underground Storage Tanks, UXO (Unexploded Ordnance) and Contaminant Plumes	Magnetic, Electromagnetic, GPR, Acoustic Pipe Tracer, Metal Detectors, Resistivity, Induced Polarization, Refraction
Vibration Measurements	Vibration Caused by Traffic, Construction, and Blasting	Vibration Monitoring

projects due to complications associated with the cost of equipment rental, mobilization, and deployment; complexity of the technology; extensive data refinement and analysis requirements; perceived application limitations; and difficulties interpreting survey findings. Today, however, geophysical imaging and geophysical methods are finding renewed acceptance in the transportation community after advances in rapid, user-friendly data acquisition; simplified data analyses; improved survey presentation; and lower deployment costs.

Engineers have adapted seismic methods for condition evaluation of pavements, concrete slabs, and walls, producing a technique known as the ultraseismic test. In this method, engineers transmit acoustic energy through a concrete structure itself, instead of the ground, with sound reflection coming from either the bottom of the structure, as in a bridge foundation, or a defect zone. Similarly, engineers now routinely use the GPR method, originally developed for high-resolution imaging of the subsurface, for structure condition evaluation. Highway engineers use these types of geophysical investigations in the transportation and infrastructure systems to evaluate new structures for quality assurance and in-service structures for forensic and quality control purposes.

3-D Tomography Using Seismic Reflection Or Refraction

For subsurface characterization, volumetric imaging provides information that engineers can use to more fully evaluate site conditions. Standard practice in geophysical surveys involves using seismic refraction techniques to produce two-dimensional (2-D) cross sections of the subsurface. The state of the practice for nearly three decades has been to process refraction data with layer reconstruction techniques using the generalized reciprocal method, time-intercept, and similar approaches. In the past decade, however, advances in computer technology and development of tomographic modeling algorithms have greatly increased the ability to detect subsurface anomalous features, increase lateral and vertical resolution, and provide more accurate graphical presentation of data.

Researchers used the seismic reflection technique to create detailed volumetric images to compare various alternatives for rehabilitating the Mount Carmel Tunnel in Zion National Park, UT.

Tomography refers to imaging by sections or slices. Typically, engineers create 2-D tomographs to image areas, while three-dimensional (3-D) tomographs help them visualize volumes. Using raw seismic data collected with sensors, engineers can create 3-D tomographs they can then analyze to measure quantities of subsurface materials.

Recently, FLH engineers have shown that 2-D finite element modeling of seismic refraction data can successfully image discrete anomalies such as voids. Advances such as 3-D seismic refraction tomography provide substantial enhancements over traditional line surveys, which makes the method a cost-effective supplement to any conventional drilling program.

Seismic Reflection at A Mountain Tunnel

In July 1930, workers completed the 1.1-mile (1.8-kilometer)-long Mount Carmel Tunnel, which provides direct access to Utah's Bryce Canyon National Park and Arizona's Grand Canyon National Park through Zion National Park in Utah. Although it was the longest tunnel in the United States at the time of construction, it is not currently large enough to accommodate two-way recreational vehicle traffic. As traffic volumes increase, FLH is working with the National Park Service (NPS) to study several alternatives to improve traffic flow through Zion. These alternatives include enlarging the existing tunnel and constructing a parallel tunnel.

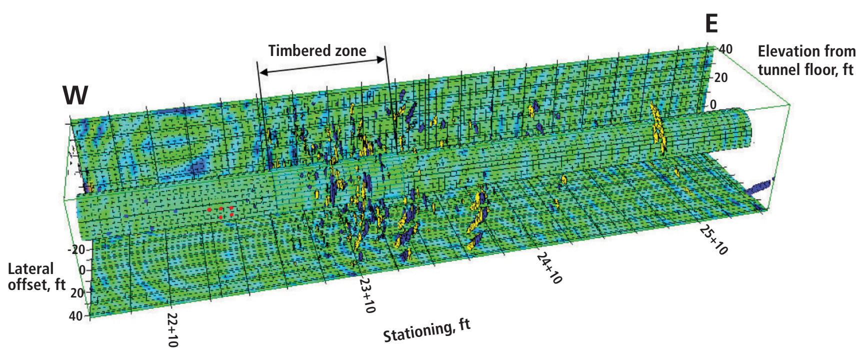
To appraise preliminary alternatives for technical and economic feasibility, FLH needed to characterize the ground conditions around the existing tunnel. To make these measurements with minimal interruptions to traffic, the team employed a proprietary seismic reflection/holography technique. This technology analyzes the seismic signals for multiple source and receiver locations, identifying reflector zones within the rock mass that might correspond to voids, fracture zones, or significant changes in geologic structure. The team verified the tomography technique by comparing the images to known ground supports and voids.

"The nondestructive seismic reflection method provided rapid characterization of large tunnel segments as well as identification of structural 'targets' warranting more detailed investigation," says Khamis Haramy, geotechnical engineer with the Central Federal Lands Highway Division (CFLHD). "The information generated from this technique enabled engineers to compare cost-benefit analyses of various alternatives."

Seismic Refraction and Compaction Grouting

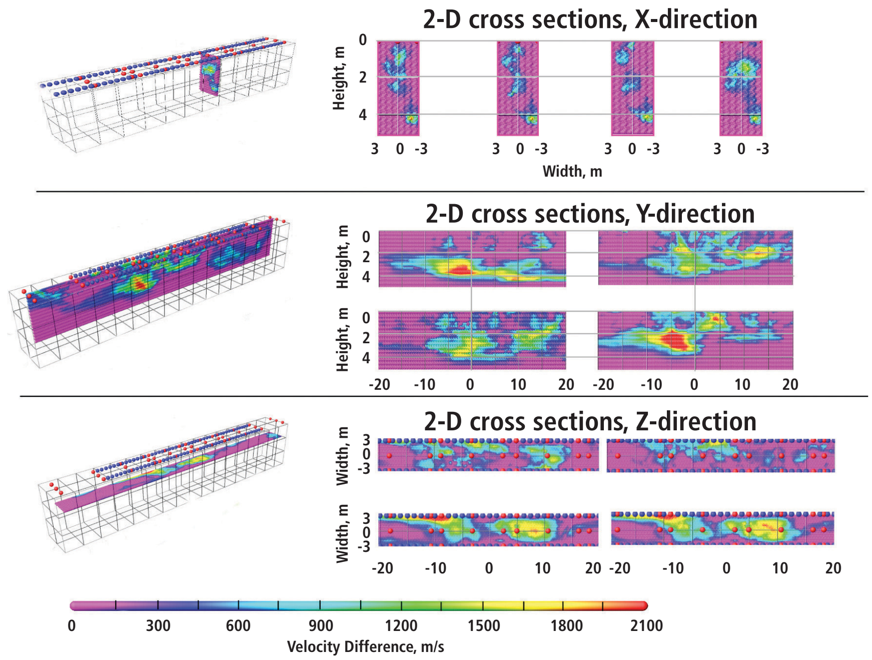
In Colorado's Rocky Mountain National Park, NPS needed to

Volumetric Image of Mount Carmel Tunnel



This 3-D volumetric image for Mount Carmel Tunnel shows weaker zones and rock cracks. The green color shows solid rock, while the other colors indicate the presence of cracks or weakened rock. *Source: FHWA.*

Difference Tomograph for Grouting



These grouting tomographs show images of velocity differences in meters per second (m/s) at different locations between pre- and postgrouting of a rock wall at State Highway 149, 7 miles (11.3 kilometers) west of South Fork, CO. The higher velocity difference shows that the voids were filled at those locations. *Source: FHWA.*

rehabilitate a historic, 50-foot (15-meter)-high, dry-stack wall (rock wall constructed without mortar) on Trail Ridge Road. After consultation with NPS, the design team selected compaction grouting as the preferred solution. Compaction grouting is a ground treatment technique by which low-mobility cement grout is injected into the ground mass under pressure. The grout fills voids or rock fractures and displaces loose soils in the subsurface, consolidating the treated ground mass in place. Engineers normally apply this technique on a grid pattern, and workers inject the grout vertically through grout tubes, forming grout columns. Engineers often use this treatment in highway applications to improve stability by filling voids in rock walls or armored slopes.

FLH used a new high-definition seismic imaging (HDI) system to gauge the subsurface conditions before and after grouting. This imaging technique, using seismic tomography, involves state-of-the-art algorithms to produce 3-D images of subsurface conditions. This relatively inexpensive seismic method proved effective in producing accurate images before and after grouting. The technique also produced difference tomograms that depict the effects of grouting, including the resultant grout columns and ground densification characteristics, which demonstrate that the majority of the wall voids are filled.

"The HDI method can be an effective tool for use with grouting methods to enhance the quality assurance methods and monitor volumetric grout injection with the improved soil mass," says Haramy. "Accurate images are produced in near real time, providing immediate confidence in survey results and allowing adjustments of receiver placement to zero in on regions of interest."

3-D Tomography Using Crosshole Sonic Logging

As the number of projects using deep foundations (such as bridge piers and abutments constructed on drilled shaft foundations) increases, highway agencies are increasingly interested in detecting construction defects occurring during concrete placement. Obtaining accurate and

A crew member injects grout into a dry-stack rock wall on SH–149 along the Rio Grande River northwest of South Fork, CO.

A worker monitors vibrations from the top of a pinnacle along General Hitchcock Highway, northeast of Tucson, AZ.

timely information on the integrity of concrete structures, such as drilled shaft foundations, is essential to avoid structural instability and other safety issues.

Crosshole sonic logging (CSL), also known as ultrasonic testing, is an indirect, nondestructive imaging method for detecting defects inside the rebar cage of a drilled shaft or diaphragm wall element (an underground structural element constructed using slurry trench technique). CSL has become a standard test for most transportation agencies and currently is performed on most drilled shafts in the United States and other developed countries. Before accepting CSL, FLH engineers performed quality assurance testing on a limited number of drilled shafts, primarily using the sonic echo and impulse response test.

"The gamma-gamma density logging tests are gaining popularity within the DOTs as a secondary test to the CSL test for identifying anomalies within drilled shafts," says Haramy. "CSL is mainly used to characterize anomalies that are located in the concrete between tubes, while gamma-gamma density logging identifies anomalies within a small zone around the tubes. These two methods complement one another to adequately evaluate the conditions of the drilled shaft in the subsurface."

Several variations of the CSL equipment and techniques exist, including a source (pulse transmitter) and receiver simultaneously lowered in the same tube (the single hole ultrasonic test, or SHUT), a source and receiver lowered in adjacent tubes, and a source and multiple receivers lowered in separate tubes. Researchers derived the CSL method from the ultrasonic pulse velocity test. The basic principle of the CSL test is that the velocity of an ultrasonic pulse through concrete varies proportionally with material density and elastic constants (which are relationships that determine the deformations produced by a given stress system acting on a particular material). A known relationship between fractured or weak zones and measured pulse velocity and signal attenuation is fundamental for these tests. Research shows that weak zones reduce velocities and increase attenuations.

During CSL tests, instruments are used to measure and record the apparent signal travel time between transmitter and receiver. By measuring a pulse's travel time along a known distance (between transmitter and receiver), engineers can calculate the approximate velocity as a function of distance over time. If they make a number of measurements and compare them at different points along the concrete structure, they can assess the overall integrity of the concrete.

The FLH study, *Velocity Variations in Cross-Hole Sonic Logging Surveys: Causes and Impacts in Drilled Shafts* (FHWA-CFL/TD-08-009), identifies conditions that affect the load-bearing capacity of drilled shafts by modeling various conditions and analyzing them with numerical methods. The analysis first identifies design criteria and construction procedures, and reviews nondestructive evaluation (NDE) techniques. This analysis uses results based on principles and theorems from engineering mechanics, geotechnical engineering, concrete chemistry, and geophysical engineering, which researchers analyze numerically using a proprietary software tool dubbed the Geostructural Analysis Package (GAP). GAP is a geotechnical engineering application that performs postprocessing for the CSL data, combining the numerical methods of the discrete element method, particle flow method, material point method, and finite differencing, together with engineering mechanics constitutive models, concrete chemistry models, thermodynamics models, and geophysical tomography and holography. Highway and mining engineers also have used GAP for ground characterization.

"Our study explores many concerns recently raised for drilled-shaft design, construction, and maintenance," says Haramy. "Our recommendations offer engineers a better understanding of drilled-shaft foundations to revolutionize foundation design, concrete mix design, construction techniques, NDE measurement, and defect evaluation to improve performance and efficiency."

Vibration Monitoring Case Study

Recent construction along the General Hitchcock Highway (Catalina Highway) through the Coronado National Forest, northeast of Tucson, AZ, raised the possibility of harmful vibrations on natural geologic formations, including rock pinnacles and a natural rock bridge. "To characterize the constructability of the roadway

A worker uses a magnetometer to survey ground mass over known lava tube locations in Lava Beds National Monument, CA.

without damaging these protected natural resources, an FLH study defined the natural vibration properties and construction vibration response of selected pinnacles and natural bridges along the project," says Matthew DeMarco, geotechnical engineer with CFLHD. "What added complexity to the study was the fact that these features ranged in height from a few meters to upwards of 20 meters [66 feet], possessed various slenderness ratios, were composed of more than one distinct rock unit, and were subject to a wide range of mechanical and blast-induced vibrations associated with road construction," DeMarco says.

Altogether, engineers investigated 20 pinnacles and one large natural bridge for their vibration response parameters—natural frequency and vibration damping. The engineers also documented the induced vibrations from the onsite hoe ram (hydraulic hammer), compactors, normal forest traffic, and several test blasts, and analyzed them with spectra analyses to characterize the vibration sources. The engineers also derived induced vibration attenuation functions for one compactor, the hoe ram, and a test blast. They then combined analyses of pinnacle response, equipment vibration, and ground attenuation to identify pinnacle features at risk from planned construction activities.

Based on the low damping characteristics measured, the study identified only two pinnacles that showed potential for instability. Both had natural frequencies generally below the higher amplitude vibrations induced by the compactors; however, the smaller pinnacle seemed to be affected by lower mode vibrations associated with compactor harmonics. The study concluded that the pinnacles were robust, with minor exceptions, and not overly susceptible to construction vibration damage. FLH modified plans (because of minor exceptions) and constructed the road without harming the natural geological features.

Detecting Subsurface Voids

Lava tubes are natural conduits through which lava travels beneath the ground surface. The tubes form when lava channels crust over after cooling. Depending on the thickness of the material above them, lava tubes beneath a roadway could pose a significant risk to the long-term stability of a roadway and public safety.

At Lava Beds National Monument in northern California, NPS staff were concerned that lava tubes posed significant risks to roadway construction, long-term stability and maintenance of the roadway, and public safety. To address these concerns, FLH used several geophysical techniques for locating near-surface voids that could affect roadway stability.

The main objectives of the study were to detect subsurface voids in specific geological settings, detect and characterize the vertical and horizontal extent of the voids, determine the most economical and time-efficient geophysical method to use during roadway site investigations, and identify the range of applications of such methods nationwide. FLH researchers collected geophysical data at the site using GPR, magnetics, high-resolution shear wave seismic reflection, electrical resistivity, and electrical conductivity. The researchers knew the geometry and location of voids at each test site, and used the information to assess the accuracy of each geophysical method they applied to detect the voids.

"The results of the investigation indicated that some of the geophysical methods were effective in detecting voids, while other methods were limited due to the localized geological setting and void geometries," says CFLHD's DeMarco. "Depending on site conditions, such as subsurface geology or void size and depth, when a combination of methods was used, there was a greater chance of effectively delineating the location and orientation of the voids."

The researchers determined that the combined GPR and magnetic methods were the most economical and least time consuming for detecting voids with depths of 0–30 feet (0–9 meters). They recommend that engineers perform magnetic surveys first as a reconnaissance tool to locate the position of magnetic anomalies that might indicate large potential voids. The next step would be to conduct a focused GPR survey to evaluate each magnetic anomaly and determine the depth and lateral extent of the features.

Electromagnetic Induction And Clay Seam Mapping

The presence of clay beneath a roadway poses problems for rehabilitation design and construction. Roads constructed over clay could be subject to differential settlement and deformation due to changes in volume caused by swelling or shrinking, low shear strength, high moisture content, and clay structure, including dipping or horizontal bedding. To understand the behavior of soil in situ, geotechnical engineers typically take soil borings at 0.25- or 0.5-mile (0.4- or 0.8-kilometer) intervals.

Although direct soil sampling provides the best information in terms of soil type and Atterberg limits (a series of thresholds observed when the water content of a soil is steadily changed), the boring intervals could miss critical clay-rich zones, and the geologic interpolation between borings might not be representative, missing large expanses of clay. Geophysical techniques such as electromagnetic induction (EMI), however, could provide a better understanding of overall type distribution of soil behavior.

The frequency domain EMI method for mapping clay beneath roadways fills the gap between soil sampling locations. Soil conductivity information derived through EMI methods can provide valuable qualitative information for evaluating road-base materials during the design phase. This information can guide soil boring by targeting the most likely locations with potential swelling clay problems.

FLH engineers used various EMI instruments on State Route 537 (SR-537), in Rio Arriba County, NM, to map the extent of clay soils. The EMI also was used for a more detailed investigation at the Natchez Trace Parkway in Mississippi to locate clay-rich zones beneath long stretches of roadway.

The SR-537 investigation concluded that frequency domain EMI profiling would be the only cost-effective, rapid way of mapping in sufficient detail the lateral extent of clay soils in the road base. The Natchez Trace study demonstrated EMI's efficiency in mapping the spatial variation of soil conductivity within the road base.

FLH's geophysical investigations demonstrated the effectiveness of EMI, which can focus drilling programs during project site investigations, road rehabilitation, and construction. The method also can provide significant financial savings by avoiding construction cost overruns.

Leading the Way

To build and maintain safe roadway infrastructure, engineers need the ability to "see" inside rock masses before blasting, "see" that grout has in fact filled voids, and "see" that no clay seams are located under roadbeds. As technology evolves and provides better tools for exploring below the ground's surface and inside manmade structures, FLH engineers now are "seeing" where previously they could only estimate. Using geophysical technologies is likely to become standard practice in the future. In the meantime, FLH is pioneering the way for others to follow.

Amit Armstrong manages the technology deployment program at WFLHD in Vancouver, WA. He has been with FHWA for 7 years, coordinating deployment of new, innovative, emerging, and underutilized technologies in design and construction of roads on Federal lands projects. He has more than 20 years' experience in numerical simulation and visualization of natural systems, and is a licensed professional engineer. He earned a doctorate in civil engineering from Texas Tech University.

Roger Surdahl joined FHWA in 1987, after receiving a master's degree in civil engineering from Montana State University. He is a registered professional engineer in Colorado. As the technology delivery engineer for CFLHD, he brings a wide range of experience in highway materials, contract administration, and innovative solutions to transportation problems.

H. Gabriella Armstrong is an information technology consultant. When she is not writing in code, she freelances on food, culture, and travel. She received a bachelor's degree in comparative literature with a minor in Spanish from the University of Colorado.

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This photo of Merrill Cave at Lava Beds National Monument shows the void under the roadway. This void reduced load rating significantly, and special precautions will be required if future construction with heavy equipment is needed at this location.

by R. Kent Barnard

Public involvement, full road closure, and new technologies helped the State speed completion of a reconstruction project.

A Mix of Innovations Succeeds in Minnesota

(Above) North St. Paul's iconic snowman oversees construction on Minnesota Highway 36. Constructed from metal and stucco, the snowman is a city symbol, a permanent replacement for the large snowmen built each winter by the Jaycees to celebrate the city's annual Snow Frolics event. In the foreground is the concrete structure that will support the Margaret Street bridge, one of three bridges built during the reconstruction project. *Photo: R. Kent Barnard, MnDOT.*

As the Nation's roadways age and become increasingly overcrowded, departments of transportation (DOTs) continually look for ways to maintain service delivery during construction projects. From accelerated construction techniques and prefabricated elements to innovative contracting and road safety audits, DOTs have a growing range of strategies at their disposal to improve safety, maintain traffic throughput, and minimize construction-related headaches for nearby residents and daily commuters.

The Federal Highway Administration's (FHWA) Highways for LIFE (HfL) program helps identify, promote, and accelerate adoption of these technologies and innovations. HfL's goal is to improve safety and highway quality while reducing congestion caused by construction. The HfL Web site highlights more than 40 success stories culled from across the United States—ranging from installing precast concrete bridge decks on Alaska's Dalton Highway to using full road closure during reconstruction of the Grand

Loop Road in Yellowstone National Park in Wyoming. One aspect of the HfL program is the provision of funding to assist States in construction projects using innovative approaches. Thus far, 17 projects have been funded in 15 States, featuring more than two dozen innovations.

A project in Minnesota, one of the first to receive HfL funding, demonstrates how combining a number of innovations and best practices can contribute to a successful reconstruction and build goodwill among motorists and nearby businesses and residents. In early 2006, officials with the Minnesota Department of Transportation's (Mn/DOT) Metropolitan District faced the dual challenges of reducing congestion on a busy urban highway and ensuring safe pedestrian passage across the roadway. A 2-mile (3.2-kilometer) segment of Highway 36, a high-volume, commuter-heavy roadway, passes through North St. Paul, a small city east of St. Paul, MN. The highway divides the city of nearly 12,000 into a northern and southern section. Congestion had become an issue for motorists who often had to stop for six at-grade intersections along the short route through the city.

Mn/DOT and city officials also were concerned about pedestrian safety, as students at the city's North High School had to cross the busy highway in the mornings and afternoons. In fact, the need for a safe crossing for students was the driving force behind the project, which began with plans for an elevated pedestrian crossing and eventually morphed into full-blown highway reconstruction.

In executing the Highway 36 project, Mn/DOT Metro District personnel and North St. Paul city officials deployed a mix of innovations that helped make the project a success. Specifically, Mn/DOT surveyed the public about whether to partially or fully close the road during construction, reached out to local businesses and residents affected by the project, and applied new technologies to get the job done faster.

Next to the snowman sculpture is the Minnesota Department of Natural Resources' Gateway State Trail bicycle-pedestrian route, built alongside the highway.

R. Kent Barnard, Mn/DOT

R. Kent Barnard, Mn/DOT

As the driving force for the project, this pedestrian bridge over Highway 36 enables students to have safe passage to and from North High School.

R. Kent Barnard, Mn/DOT

Crews from Mn/DOT's foundation unit used the equipment in these trucks to conduct preliminary soil borings to determine the soil composition near the snowman. Information on soil composition led to a decision to place sheet piling near the iconic sculpture to protect it during nearby excavation.

"Mn/DOT's efforts exemplify the effective application of HfL ideals and approaches," says Kathleen Bergeron, marketing communications coordinator for FHWA's HfL program. "Use of innovative market research techniques and a detailed, multifaceted public involvement and communications program helped build trust with the community, ultimately leading to success for this project."

Market Research

For a number of years, North St. Paul city officials had been discussing the need for a safe pedestrian crossing over Highway 36. Grassroots mobilization eventually brought the issue to Mn/DOT's attention, and subsequent planning discussions expanded the scope of the project from the addition of a pedestrian crossing to full reconstruction of the highway. During the planning phase, highway designers at the Mn/DOT Metro District faced a critical decision about whether to close the road partially or completely during construction. Planning studies revealed that partial road closure would result in 16 months of lane closures, while full closure would shut down that section of road for just 5 months, with traffic detouring around the construction site. Full closure therefore offered a 70 percent reduction in the duration of traffic impacts.

Given the expected impact of road closure on commuters and downtown businesses and residents, Mn/DOT enlisted the help of in-house market researchers to gather information the engineers could use to support a decision to use partial or full road closure. Rather than leave the decision entirely up to the engineers, Mn/DOT public affairs and market research staff posed the question to the community: Would they prefer partial or full road closure during construction? In February 2006, the department enlisted a market research firm to help conduct phone surveys of residents, commuters, and local businesses. The researchers described the two scenarios—full closure for 5 months or partial closure for 16 months—and gathered respondents' preferences. In the end, the researchers surveyed 1,074 people, with the results split nearly 50/50.

Because the surveys did not reveal a clear public preference one way or the other, Mn/DOT's market researchers took this as an opportunity to rely on the department's best technical data. Weighing the benefits, Mn/DOT opted for full closure, which would allow faster construction, be less expensive and safer for workers and motorists, and yield a higher quality roadway.

Community Outreach And Events

Public involvement on this project did not end with the phone surveys. Recognizing that full road closure would detour traffic away from downtown North St. Paul, the department took steps to reduce the impact on city residents and businesses. Specifically, Mn/DOT hosted open houses and workshops in North St. Paul, the community most affected by the construction. At these meetings, representatives from Mn/DOT showed layouts and timelines for the project stages and answered questions from the public.

During construction, the department provided regular updates at city council meetings and business and local organization gatherings.

Mn/DOT also sponsored a meeting in nearby Maplewood, a city located at the edge of the project area.

Additional meetings with business groups in North St. Paul provided a forum to brainstorm advertising and marketing ideas with local merchants to help them attract customers to their businesses during construction. A workshop, "Open for Business—Surviving and Thriving During Construction," presented by Mn/DOT, drew more than 150 people. The workshop provided an overview of the project and the anticipated traffic patterns, and then shared sample marketing tactics such as holding construction-themed sales to let customers know the businesses were still open during construction and printing project information on placemats at local restaurants. Mn/DOT stressed to merchants the value of projecting a positive attitude and offering good service as ways to entice customers to find alternative routes to their businesses during the highway closure.

Mn/DOT also sponsored events targeting the broader community. For example, a group of local businesses, city officials, and staff from Mn/DOT Public Affairs hosted a celebration christened "Detour Days" to mark the highway's official closing. The celebration included a 3-mile (5-kilometer) road race, a coloring contest for children, and local vendors selling food and other items. Other special events marked project milestones, such as the grand opening of a pedestrian bridge crossing the highway. An old-fashioned Christmas celebration in downtown North St. Paul also became part of the city's roster of events and continues to this day. The holiday celebration included a visit from Santa Claus, a dance, and special offers at area restaurants. Local businesses even hosted their own events. For example, a kung fu studio invited children to decorate Christmas ornaments.

"Mn/DOT worked extensively with the citizens and businesses to make this project as painless as possible and provide some benefits for them," says Jan Walczak, North St. Paul city council member and city council liaison to Mn/DOT.

In addition, the department distributed news releases covering not only construction updates but also community events—an uncommon combination of purposes for DOT news releases. Weekly updates from the project engineer were sent to an e-mail list and posted on the project Web site, which was set up well in advance of project startup. Mn/DOT also posted photographs of construction activity on the project's Web site. Media coverage included regular project updates and stories on activities to celebrate milestones. By the end of the project, 677 people had signed up for the project's e-mail updates.

Innovative Technologies

In addition to the public involvement efforts, Mn/DOT applied innovative construction techniques on the Highway 36 reconstruction, including machine control technology and intelligent compaction.

Machine control involves applying global positioning system (GPS) technology to the operation of earthmoving equipment such as bulldozers and road graders to establish the grade. Mn/DOT operators relied on real-time GPS satellite transmitters to monitor equipment movement and determine exactly where earth needed to be excavated or filled.

The North St. Paul Snowman

Following reconstruction, North St. Paul's iconic snowman continues its vigil along Highway 36. Standing 44 feet (13 meters) high and weighing many tons, North St. Paul's snowman has stood watch over the city for more than three decades. The metal and stucco snowman was conceived by a local businessman following a visit to Disneyland. He felt the city and the local business community could benefit from a larger-than-life icon.

The massive city symbol replaced large snowmen built each winter by the Jaycees to celebrate the city's annual Snow Frolics event. Several years of minimal snowfalls in the late 1960s and early 1970s had made it difficult to truck in enough snow to build an adequate snowman, and the stucco creation replaced the real thing.

Construction of the snowman began in 1971 and was completed in 1974 with all volunteer labor at a cost of $2,000 for materials. It originally was located at the corner of 7th Avenue and Margaret Street in downtown North St. Paul but was moved in the early 1990s to its current location overlooking Highway 36 at Margaret Street.

Crews took special care to protect the snowman during reconstruction of the highway, including drilling preliminary soil borings to determine the soil composition and driving pilings to support the huge snowman. With work on Highway 36 and the Margaret Street bridge completed, the snowman remains on duty "watching" local citizens and traffic on the highway.

These carolers are singing in front of a shop in downtown North St. Paul as part of an old-fashioned Christmas celebration kicked off during the Highway 36 project.

Jan Walczak, North St. Paul City Council

Three-dimensional computer models helped monitor progress and indicated when the correct amount of aggregate had been placed. This technology helped minimize or eliminate the need for placing stakes in the ground, saved time, and helped ensure a smooth driving surface when the project was complete.

"We have effectively used machine control on many of our projects and are continuing our efforts to fully implement this technology," says State Construction Engineer Tom Ravn, in the Mn/DOT Office of Construction and Innovative Contracting.

Another innovative technology used during the reconstruction was intelligent compaction, which equips rollers with sensors that precisely measure the stiffness or compaction of the ground and roadway materials beneath them. Integrating measurement, documentation, and control systems, intelligent compaction rollers allow for real-time corrections in the compaction process. By reading a computer screen that identifies the compaction of the grade, roller operators could easily identify soft areas in the roadway that needed additional compaction and avoid over-compaction and aggregate crushing, which could ultimately lead to loss of structural support.

"Ongoing research in this area has allowed us to improve our specification and quality of our embankment construction," Ravn says. "We will continue to refine the technology based on these research results and experience on future projects."

R. Kent Barnard, Mn/DOT

Global positioning equipment mounted on this roller enabled operators to establish the grade for Highway 36 during the compaction process.

Epilogue

Although construction of the entire highway was not completed until late summer 2008, Mn/DOT lifted the road closure a full year earlier—in August 2007—in fewer than the 5 months predicted. In spring 2008, the market research team launched a followup survey of residents, businesses, and commuters to evaluate the closure portion of the project.

The market researchers added a series of questions addressing signage, communications, access, and road closure to the initial Highway 36 survey. They kept questions as close as possible to a survey that Mn/DOT used for a statewide tracking study called the Community Construction Evaluation project, which the Office of Construction and Innovative Contracting adopted as a best practice after evaluating five Minnesota projects in 2005. Mn/DOT therefore could compare the results from the Highway 36 survey to those of surveys following projects without full closures.

Overall, survey respondents were overwhelmingly positive about the closure and the progress of the entire construction project. Nine out of 10 respondents from each audience segment surveyed (residents, businesses, and through commuters) reported strong or somewhat strong agreement with the decision to close the highway. For those who agreed with the closure decision, the most common reason was that it allowed the project to be completed much faster. According to Chris McMahon, director of Mn/DOT's Market Research unit, this finding supports a growing trend since the 1990s in Minnesota that shows the public prefers more inconvenience over a shorter time rather than less inconvenience over a longer period.

Other benefits such as safety aspects and money saved with the closure ranked highly among those surveyed. Respondents reporting negative opinions about the closure cited a perception that the closure had a negative effect on local businesses and caused inconvenience to motorists.

Many respondents who initially reported being against full closure changed their minds as of the followup survey. At least two in five respondents in each audience segment (and nearly half of business respondents) changed their opinions toward the positive compared to their preproject responses. Fewer

Hear Every Voice

In 2009, Mn/DOT's public involvement process, "Hear Every Voice," celebrates 10 years of reaching out to the public for input on important transportation issues affecting the State. The initiative began in 1997, when Mn/DOT assembled a task force to review and update procedures for involving the public in the department's program delivery decisions. Two years later, Mn/DOT released its guidance document *Hear Every Voice: A Guide to Public Involvement at Mn/DOT*. The booklet covers the role of public involvement in planning and project development, including case studies and tools to assist in selecting appropriate techniques.

Mn/DOT, in conjunction with the FHWA Minnesota Division Office and the Minnesota Local Technical Assistance Program, recently updated its guidance materials for public and stakeholder participation in transportation projects. The updated components include a new Web site, a training curriculum that addresses managing effective public involvement, and a revised version of Mn/DOT's public involvement guide, *Hear Every Voice: A Guide to Public Involvement at Mn/DOT*.

For more information, visit www.dot.state.mn.us/pubinvolve/partner.html.

Minnesota Highway 36 at the intersection of Margaret Street before (right) and after (below) the reconstruction project. The new alignment is below grade, improving traffic flow and safety through the area. *Photos: R. Kent Barnard, Mn/DOT.*

than 1 in 10 respondents in each segment changed their minds toward the negative.

Even though the results of the postclosure survey revealed that the community deemed the project a success, McMahon cautions that each community is likely to be different, and some might be much more averse to a full closure. "North St. Paul was a community split in two by the highway, which likely promoted favorable response to the closure, since the construction would eliminate the bottleneck for residents traveling from one side of the town to the other," she says. Further, McMahon recommends using market research techniques to survey a community and through travelers for reaction before making decisions about full closure.

"Going the extra mile with the market research and working with residents and businesses to devise and promote community events around the construction was critical to the project's success," McMahon adds. "That extra effort paid off. Although there was opposition to the highway closure, by being accessible and responding to concerns, we were able to soften the effects of construction through North St. Paul and actually gain support for the work."

And what of the pedestrian safety and accessibility issues that initially inspired the project? Most of the construction took place between May and August, largely during the summer months when the students would be away from school. Now students and others can safely cross Highway 36 by way of a new pedestrian bridge or the new bridge at Margaret Street. Plus, with the highway now below grade, Mn/DOT has eliminated the old at-grade crossings, enhancing safety for pedestrians and improving traffic flow for motorists.

R. Kent Barnard is a communications and media specialist in Mn/DOT's Metro District. He began his career with Mn/DOT in 1989 as editor of the internal newsletter *Mn/DOT Today* and as a writer/photographer for the monthly *EXPRESS* magazine. In 1992 Barnard became a public affairs coordinator, and since then he has covered construction projects in the north and east Twin Cities metropolitan area, including reconstruction of Highway 36. He is a graduate of the University of Minnesota Duluth with a bachelor's degree in communications and political science.

For detailed information about the market research report, contact Chris McMahon at 651-366-3771 or chris.mcmahon@dot.state.mn.us. Information about the communications and marketing on the project is available from R. Kent Barnard at 651-234-7504 or kent.barnard@dot.state.mn.us. For more information on Highways for LIFE, visit www.fhwa.dot.gov/hfl.

Exploring Vehicle Size And Weight Solutions

by Jodi Carson and Tom Kearney

A scan tour in Europe demonstrated a number of innovative strategies for enforcing commercial motor VSW regulations.

(Above) In the Netherlands, the U.S. scan team inspected this $1.2 million weigh-in-motion calibration vehicle, which eliminates traditional dynamic-to-static measurement adjustments and the associated loss in accuracy. *Photo: George Conner, Alabama Department of Transportation (ALDOT).*

Commercial motor vehicle size and weight (VSW) requirements are in place for roadway safety and infrastructure preservation. However, the amount of infrastructure damage an overweight vehicle causes is geometrically larger than the weight increase; for example, an increase in axle weight from 18,000 pounds to 20,000 pounds causes 50 percent more damage to the pavement. Given the capital investment currently spent to maintain existing infrastructure—88 percent of the total amount of Federal-Aid Highway Program funds in 2007 were obligated for restoration and rehabilitation, resurfacing, and reconstruction—it is critical that adequate size and weight enforcement be in place.

Even as the transportation community needs to maximize the service life of existing assets, the volume of freight moving on the Nation's highway system continues to grow, reflecting the increasing population and demand for goods. Transportation professionals must find a way to accommodate this growth while preserving infrastructure. Legal loads must be allowed to move unencumbered throughout the system to improve the efficiency and productivity of truck carriers, and illegal loads must be caught and penalized. The challenge is increasing the use of technology and forward-thinking practices and procedures to intelligently target enforcement activities to ensure safety, preserve the Nation's infrastructure investment, and improve truck productivity.

To improve the efficiency and effectiveness of VSW enforcement in the United States, the Federal Highway Administration (FHWA), American Association of State Highway and Transportation Officials (AASHTO), and National Cooperative Highway Research Program (NCHRP) conducted an international scan tour in 2006 to six European countries that are using innovative practices, procedures, and technologies to enforce VSW. "The scan reviewed and evaluated contemporary European procedures and technologies for enforcing commercial motor vehicle size and weight laws and regulations," says Jeff G. Honefanger, cochair of the scan tour and manager of the Ohio Department of Transportation (ODOT) Special Hauling Permits Section.

Based on the scan team's observations, the near-term activities to support U.S. implementation include a pilot installation of a bridge weigh-in-motion (WIM) system on a representative structure, a demonstration of the European mobile enforcement approach to prescreening suspected overweight vehicles, a case study describing the effective use of WIM data, and a synthesis of existing research on linkages between overweight commercial motor vehicles and roadway safety. Additional strategies intended for investigation for potential U.S. implementation include a heavy goods vehicle control facility modeled after facilities observed in Switzerland, the use of WIM systems for direct enforcement, and behavior-based enforcement activities that target habitually noncompliant carriers.

The Study's Locales, Participants, and Focus

Using information obtained from published literature, various Internet sites, reports on previous scanning studies related to the subject, and U.S. and European experts in the field, the scan team selected the following locales for the study: France, Germany, the Netherlands, Slovenia, and Switzerland. In addition to visiting these countries, the scan team met with members of the European Union (EU) in Brussels, Belgium, to gain perspective on efforts to harmonize VSW enforcement activities among EU countries.

A team of U.S. experts in commercial motor VSW enforcement conducted the scan study. The 10-member team included three members from FHWA, five from State departments of transportation (DOTs), one from law enforcement, and one from academia. One of the members from FHWA and one from the Ohio Department of Transportation, representing AASHTO, led the team. In addition to breadth in agency types, the scan team had varied expertise in VSW technologies, procedures, data applications, public-private involvement, and harmonization.

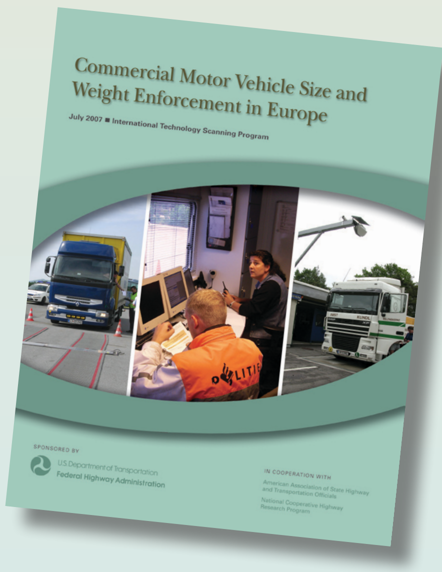
The scan study considered five specific aspects of European VSW enforcement:

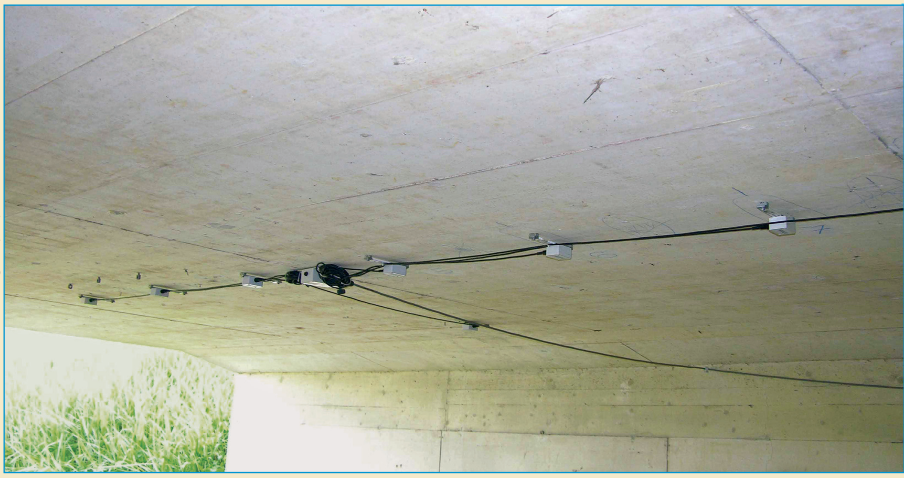
- Emerging VSW enforcement technologies, including third-generation WIM systems that can produce reliable evidence of specific violations capable of withstanding legal challenge
- Unconventional VSW enforcement procedures, including alternative performance-based programs
- Novel uses or applications of WIM data to support pavement design, bridge and structural design, traffic engineering, transportation planning, and ongoing performance monitoring and evaluation of VSW enforcement programs
- Innovative public-private funding mechanisms for VSW enforcement technologies and programs
- Multinational programs to harmonize administrative and operational VSW enforcement among member countries

Concurrently, the scan team considered intrinsic benefits related to infrastructure preservation, enforcement efficiency and effectiveness, commercial motor vehicle productivity, emissions, safety, and data quantity and quality. Complete documentation of the scanning study, *Commercial Motor Vehicle Size and Weight Enforcement in Europe* (FHWA-PL-07-002), is available electronically through the FHWA Office of International Programs (OIP) (see below).

Enforcement Technologies

Two of the six countries visited, Switzerland and Germany, use technology to support enforcement of commercial motor vehicle size regulations. To permit direct enforcement, the Swiss use an automated vehicle profiler system in low-speed applications of less than 6 miles per hour, mi/h (10 kilometers per hour, km/h). The gantry-mounted system, installed at off-route stationary enforcement locations, uses laser scan technology to provide a full three-dimensional (3–D) profile, including the height, width, and length of a vehicle. Two laser scanners mounted on a gantry capture the height and width measurements, and a third scanner mounted on another gantry captures the length. As a vehicle passes under the gantries, accompanying software creates a 3–D model that can be rotated in any direction for analysis. This system provides a more complete and accurate 3–D picture of a vehicle than is provided by conventional manual methods using a measuring tape or bar, and allows enforcement officials to focus on other aspects of inspection.





Pam Thurber, Vermont Agency of Transportation (VTrans)

Shown here are strain gauge and data hub instrumentation for bridge WIM technology on the underside of a concrete bridge deck near Ljubljana, Slovenia.

For high-speed applications, the Germans use the same gantry-mounted vehicle profiler system, installed along 7,456 miles (12,000 kilometers) of German autobahn as part of its larger toll collection system, to preselect potentially oversized vehicles from the traffic stream.

To support enforcement of commercial motor vehicle weight regulations, Slovenia is using a bridge WIM system successfully and extensively for a variety of applications, including preselection for mobile enforcement; remote field verification of permitted overweight vehicles; alternate route monitoring for possible bypass by noncompliant vehicles; and data support for planning, design, and structural analysis. Bridge WIM systems use strain transducers or gauges attached to the bridge soffit or embedded in the bridge deck, plus onroad axle detectors or Nothing-On-the-Road/Free-of-Axle Detector (NORFAD) systems to provide information on axle and gross weights, axle spacing, speed, and position for commercial motor vehicles and other vehicles traveling at highway speeds. To date, the Slovenian bridge WIM system has proven most successful on short, stiff structures with integral concrete slabs.

France is testing WIM systems on a variety of bridge types, generating interest among some of the other countries visited during the scan tour. In addition, the Netherlands recently installed a bridge WIM system for testing on Dutch highways and now is identifying other bridges for potential implementation.

The scan team also observed conventional inroad WIM systems to be used widely, although the extent of technology implementation varied by country. By developing a European WIM system specification (called the COST 323 specification), the EU encouraged consistency in the selection of technology deployment sites and determination of measurement accuracy. The scan team also noted a general consistency in the use of low-cost WIM sensors such as piezoquartz or piezoceramic sensors, which estimate dynamic vehicle loads based on the proportional voltage differential that results when a vehicle passes over and compresses the sensor. Purported differences relate to sensor durability and sensitivity to temperature, among other factors.

Shortcomings that have been historically observed related to WIM system accuracy and maintenance have been largely accommodated in the countries visited during the scan. Novel WIM system calibration technologies and procedures help to ensure system accuracy while minimizing maintenance costs. The Netherlands has developed a dynamic calibration vehicle that eliminates traditional dynamic-to-static measurement adjustments and the associated loss in accuracy. France and the Netherlands use continuous, ongoing calibration procedures to ensure an adequate level of WIM system performance. Static axle weight records obtained during scheduled enforcement activities are directly compared for accuracy to the axle weight records captured by the WIM system for the same vehicles in near real time. If an unacceptable level of data error is observed, the problem is corrected quickly through system calibration or other remedial action.

In general, the accuracy attained by WIM systems is sufficient to support a variety of strategies intended to enhance the efficiency and effectiveness of enforcement and to provide data to support infrastructure planning and design, but it is insufficient for direct, automated enforcement (that is, issuing citations based solely on WIM measurements without the need for subsequent static measurements).

France and the Netherlands cooperatively are investigating multiple-sensor WIM technology to achieve sufficient accuracy levels to support direct enforcement of commercial

Pam Thurber, VTrans

Portable static scales are weighing this truck at a mobile enforcement site in Slovenia.

This Haenni scale mounted in the pavement surface at a mobile enforcement site in Slovenia is measuring truck axle weight.

George Conner, ALDOT

vehicle weight limits in high-speed applications but estimate this application to be 5 to 20 years in the future. Primary challenges include attaining sufficient accuracy levels for the WIM systems—that is, accuracy class A(5) in the COST 323 European specification; gaining certification approval from the national metrological bodies; and modifying existing laws that require static weight measurements.

As an interim step, France recently obtained certification approval of low-speed WIM systems for direct enforcement applications from the National Metrology Institute, allowing for an estimated tenfold increase in the number of vehicles processed. The United Kingdom and Germany are already using low-speed WIM for direct enforcement, although the team did not observe this application during the scan tour.

Enforcement Procedures

In several of the countries visited, the scan team observed a high level of collaboration in VSW enforcement among similar agencies of different jurisdictional levels (that is, national and regional law enforcement agencies) and among different agencies (such as transportation and law enforcement). In addition, private sector entities work closely with government and research bodies to refine and enhance product performance and accuracy.

The scan team consistently observed a greater use of mobile enforcement and fewer fixed roadside weigh facilities in Europe than in the United States. The European strategy results in a lower volume of trucks being processed and is challenged by limited roadside infrastructure to support vehicle inspection and offloading. Nonetheless, this approach provides greater flexibility to respond to dynamic industry loading and routing patterns, and results in higher violation capture rates (that is, the number of citations issued compared to the number of vehicles inspected) and a subsequent increase in enforcement efficiency and effectiveness.

Video technology often is used in conjunction with WIM systems to support the real-time preselection of potentially noncompliant vehicles during mobile enforcement activities. Also, it is used for the scheduling and dispatch of enforcement resources based on historic weight violation patterns, and the identification of habitually noncompliant carriers for advisory notices and preventive carrier visits.

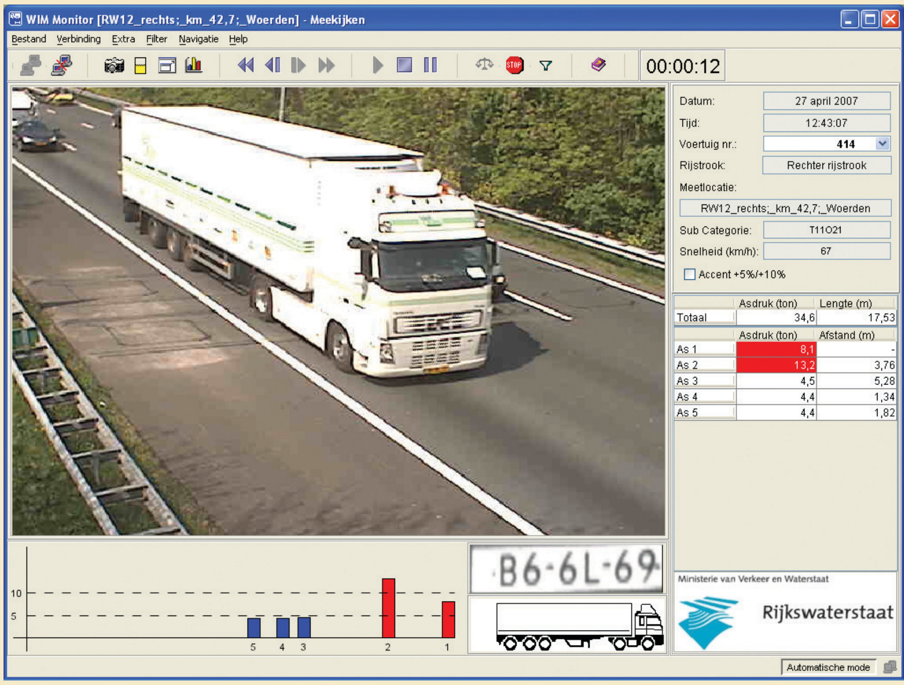
This combination of technologies also is used to support the real-time remote verification of permitted oversize/overweight (OS/OW) vehicle movements. Additional innovative procedures for addressing OS/OW permitting in the countries visited include the development and provision of Web sites allowing truck drivers to self-route based on origin, destination, and route restrictions (Switzerland) and the use of calibrated influence lines to calculate the safety of a bridge using the exact axle loadings and spacing of candidate overweight vehicle loads (France, Slovenia). Influence lines are mathematical expressions in graphical form derived from bridge WIM systems that describe the structure's response to a load anywhere along the structure.

In many of the countries visited, the potential bypass of enforcement activities by noncompliant vehicles was raised as a concern. The use of mobile enforcement procedures and low-cost technologies better positions European enforcement officials to address bypass challenges. France and the Netherlands have integrated bypass considerations into their WIM system site selection process. The Netherlands also has integrated bypass considerations into site-level system plans. On multilane facilities, WIM sensors are installed in the right two lanes; remaining lanes are equipped only with electronic loops and overhead cameras to detect bypassing vehicles. As designed, overall system costs are reduced without significantly altering the effectiveness of enforcement efforts.

Benefits from these technologies or procedures have not been extensively quantified. Swiss, Dutch, and French representatives reported general benefits related to increased enforcement efficiency through the use of technology (that is, providing greater enforcement effort with fewer human resources). The most common quantified benefit they reported related to onsite enforcement efficiency—the number of citations or warnings issued compared to the number of vehicles inspected.

Unique Data Applications

The European countries visited use WIM system data most often for supporting various enforcement-related strategies, including the preselection of potentially noncompliant vehicles during mobile enforcement



This screenshot shows the software interface used to support real-time mobile enforcement activities in the Netherlands. *Source: Hans van Saan, Road and Hydraulic Engineering Institute, Dutch Ministry of Transport, Public Works, and Water Management.*

operations, the scheduling and dispatch of enforcement resources based on historical weight violation patterns, and the identification of habitually noncompliant carriers for advisory notices and preventive carrier visits. Use of this data to support planning, historical trend analysis, policy and pricing decisions, design, structure analysis, and permitting is more limited. Information on "loadings" on the roadway networks continues to increase in its value and use for these purposes. In the United States, several States currently operate and a few others are exploring the construction of enterprise-level WIM database systems allowing multiple user access to vehicle weight data for the purposes mentioned. This type of data system offering weight data to a wide variety of customers was a common feature of the WIM programs operated by each of the six countries visited by the scan team.

Data quality was reported to be largely sufficient for each of these various applications. The most common shortcoming noted was the extent of geographic coverage.

Public-Private Funding

In Europe, investment in VSW enforcement often is justified through environmental impacts, road safety considerations, and infrastructure impacts. The development of enforcement approaches, tools, and techniques is driven also by a desire to maintain fair competition within the trucking industry. In the United States, primary motivators include infrastructure preservation and safety, although the basis for safety benefits is not well quantified.

Several of the countries visited use some form of tolling or pricing to help finance roadway operations, maintenance, and improvements, with a separate focus on the movement of heavy goods. The extent and nature of tolling systems varies from country to country, but often includes public-private operation of systems and weight- or size-based tolls for heavy vehicle movements. None of the tolling schedules observed during the scan tour is based on actual or real-time weights. More often, toll schedules reflect a fixed, registered weight capacity and do not distinguish between fully loaded or empty transports. This latter procedure encourages the trucking industry to operate more efficiently to avoid paying tolls for empty transports.

Similarly, the fee structure for special permits is not always based on actual or real-time weights, but instead reflects a flat-fee structure.

Emerging user fees are being investigated and developed as part of the European Eureka Logchain Footprint project. Eight EU countries are participating in the project, which aims to support development of a pan-European heavy goods vehicle surcharge, with its value determined by the unique environmental effects (noise, vibration, emissions) of a particular vehicle.

The team noted that both industry and government are sensitive toward ensuring fair competition among trucking companies. Industry is largely supportive of enforcement approaches, tools, and techniques that will help ensure fair competition. The scan team observed that, despite this industry support, direct participation by the trucking industry to address VSW enforcement challenges is minimal. The Netherlands actively sought solutions from the

A toll collection official is showing an onboard information technology system used to help enforce Germany's automated truck tolling program. *Photo: George Conner, ALDOT.*

Scan team members watch a Slovenian enforcement official operate roadside bridge WIM software on a laptop.

Pam Thurber, VTrans

industry for VSW enforcement without any initial actionable feedback. Over time, the Dutch trucking industry responded to enhanced VSW enforcement effectiveness by modifying loading behavior, enhancing self-monitoring capabilities, or adding additional axles onto new or existing vehicles to reduce per axle loads and increase compliance.

Harmonization Approaches

A common goal or priority in decisionmaking for the countries visited is creating consistency within the EU while maintaining the economic interests of individual countries.

In general, EU member countries exhibit a very high level of coordination in undertaking research. The Forum of European National Highway Research Laboratories and the EU provide the framework for administering large-scale, multiyear, coordinated research. A demonstrated outcome from such coordinated research is the COST 323 European specification for WIM systems, which has provided a common and widely accepted prestandard that all parties have used since its establishment in the late 1990s.

The European Traffic Police Network provides a framework for multinational, coordinated highway enforcement. It was interesting to note the similarity in venues for coordination among enforcement officials—the European Traffic Police Network in Europe and the Commercial Vehicle Safety Alliance in North America—and collaborative highway research endeavors—NCHRP and the Transportation Research Board in the United States and the Forum of European National Highway Research Laboratories in Europe—considering the issue of sovereignty across European nations.

Implementation Recommendations And Outcomes

Based on these general findings and observations, the scan team ranked an expansive preliminary list of European commercial motor VSW enforcement technologies and procedures identified as part of the scan. The scan team members subsequently consented to the exercise of ranking as high, medium, or low interest levels for implementation in the United States. By adopting these rankings, the team was able to identify high-priority technologies or procedures for implementation—those implementation priorities assigned the greatest potential for technology transfer and enhancements to current U.S. tools and practices for enforcing truck size and weight limits.

Several implementation opportunities, by their scope and context, were determined to overlap or, upon retrospection, appear redundant. By combining some opportunities because of perceived overlap, the scan tour implementation team (STIT) was able to focus the high-priority opportunities into seven specific areas of technology and procedure:

- Slovenia's Bridge WIM (B-WIM) System (France, Slovenia)
- Swiss heavy goods vehicle control facility operations and elements (Switzerland)
- Effective prescreening, using automated tools, to support mobile enforcement (France, the Netherlands, Slovenia, Switzerland)
- WIM for direct enforcement: a template for implementation and certification (France)
- Behavior-based enforcement activities (France, the Netherlands)
- Synthesis of the safety implications of OS/OW commercial vehicles (Belgium)
- WIM data used effectively: Dutch case study (the Netherlands)

The STIT also identified specific strategies for advancing these implementation opportunities, with various scan team members assigned supporting action items. The following sections discuss details of these implementation opportunities and outcomes to date.

Slovenia Bridge WIM System

A partnership between research staff at the Slovenian National Building and Civil Engineering Institute's research department and a private engineering firm, Centro Español de Servicios Telemáticos, S.A., resulted in the development of the SiWIM™ bridge WIM system in Slovenia.

The SiWIM system captures axle weights, gross vehicle weights (GVW), axle spacing, vehicle speed, and vehicle class. Extensive research centered on the behavior of the influence line that describes the structure's response to a load anywhere along the structure when loading is applied to a bridge deck led to the ability to estimate a vehicle's static weight within acceptable levels of accuracy. The Slovenian SiWIM has proven most successful on short-deck orthotropic bridges of 16 to 33 feet (5 to 10 meters) long.

An attractive feature of this technology is that measurement telemetry is installed on the underside of the bridge deck, eliminating the need to cut into pavement structures as is typically the case. The drawback of the Slovenian B-WIM tool is that there are limited opportunities for use based upon the size of bridge structures that accurate readings can be gained from. Research is underway currently to develop methods that would expand the population of bridge types and sizes where B-WIM could estimate effectively the static weight of commercial motor vehicles traveling at normal highway speeds.

System instrumentation can be fully applied to an underdeck location, eliminating the need to disrupt traffic during installation. The time required for installation is not significant and, once bridges are initially instrumented, the strain transducers or gauges can be easily moved among bridges, making the system highly portable. In Slovenia, five SiWIM devices are used to collect data for 1 week at 30 locations twice per year.

By eliminating the need to disrupt traffic and minimizing worker risk during installation, B-WIM systems offer major benefits over current U.S. practices. In addition, U.S. applications of B-WIM systems could enhance a broad range of capabilities for commercial motor vehicle weight enforcement and provide important information for bridge management systems. A single test site is currently under development in Alabama, with the longer term intent of deploying and evaluating B-WIM systems in additional States through a pooled fund or other approach.

Swiss Heavy Goods Control Facility

To protect highway tunnel facilities and roadway infrastructure from the impacts of OS/OW vehicles, Switzerland developed and implemented an efficient and effective approach to simultaneously capture size measurements and weight measurements at stationary enforcement locations. High-speed WIM and video systems are used in conjunction with these facilities to preselect suspected noncompliant vehicles for further inspection. Once inside the facility, vehicles are directed to drive under the gantries at low speeds so that accompanying software can create 3–D models of the vehicles and then onto a static weigh bridge that provides simultaneous axle and gross vehicle weight measurements.

An attractive element of the Swiss heavy goods vehicle control facility is the user-friendly presentation of size and weight data to the enforcement officers. A horizontal line depicts legal axle and GVW allowances; captured weight measurements that exceed legal limits are readily apparent. Similarly, captured size measurements that exceed legal height, width, or length allowances are depicted in red on the 3–D model. The system automatically generates size- and weight-related citations for issuance to the vehicle operator and submission to the courts.

Swiss enforcement personnel reported the ability to obtain more accurate measurements with less manpower, resulting in more effective and efficient enforcement. The Swiss currently operate three control centers with additional centers in the planning and development stages.

In February 2008, Swiss officials visited the United States to exchange information on technology-based approaches for commercial motor VSW enforcement. Participants included Swiss transportation and law enforcement officials and their U.S. counterparts at the Federal and State levels. During the visit, the Swiss representatives provided an overview of VSW management policies and procedures in Switzerland and a description of their heavy goods vehicle control sites. The scan team has not yet identified model deployment sites in the United States; however, the team believes that enforcement stations at key high-volume domestic or international land crossings might be beneficial.

Prescreening for Mobile Enforcement

"A significant level of interest exists in the United States in the use of automation tools and technology to improve commercial motor vehicle size and weight enforcement," says John Nicholas, transportation specialist in FHWA's Office of Freight Management and Operations and

Pam Thurber, VTrans

Swiss mobile enforcement officers are processing trucks for size and weight compliance at a heavy goods vehicle control center.

former commercial vehicle program manager at Washington State Patrol.

The scan team observed mobile enforcement activities in four of the six countries visited: France, the Netherlands, Slovenia, and Switzerland. In each case, high-speed WIM technology provides for mainline prescreening of suspected overweight commercial motor vehicles. Overweight detections trigger video capture (that is, digital photo images) of the vehicles. The system transmits weight and image data via short-range communications to enforcement personnel, enabling them to identify appropriate commercial vehicles in the traffic stream and escort them off the mainline for further investigation.

U.S. States already employ mobile enforcement to varying degrees. The scan team identified a preliminary need to characterize the nature and extent of mobile enforcement in the United States before promoting European practices. Such a state-of-the-practice review has not yet been initiated.

WIM and Direct Enforcement: Template For Implementation And Certification

In many cases, institutional barriers challenge the widespread deployment of advanced technologies for VSW enforcement. The use of WIM systems for direct enforcement requires support from both the standards bodies charged with equipment certification and judicial bodies responsible for related legal actions. Enforcement officials can test and certify low-speed WIM systems using methods similar to those employed for static weighing equipment, making deployment of the systems a logical first step toward direct enforcement. The testing and certification process for high-speed WIM systems is more complex and requires the development of new acceptance methods.

French officials are leading efforts to overcome institutional challenges, focusing initially on the use of low-speed WIM systems for direct enforcement. The Dutch are focusing on gaining acceptance of high-speed WIM systems.

Because similar institutional challenges would be encountered in the United States, the scan team recommended an indepth review of the French and Dutch evolutionary process for acceptance of WIM systems for direct enforcement, with a concurrent review of the U.S. direct enforcement climate and requirements. No such review has yet begun.

Behavior-Based Enforcement Activities

Using high-speed WIM systems and video technology, Dutch and French officials employ historical data to identify habitually noncompliant

Randy Woolley, California Department of Transportation

At a mobile enforcement site in France, officials required offloading of this logging truck.

carriers. This information is captured continuously (24 hours a day, 7 days a week), regardless of whether mobile enforcement is taking place.

Carriers with the highest historical overloading offenses are sent an initial advisory notice, enforcement officials meet at their place of business, and a monitoring period begins. If loading behavior sufficiently improves, the carrier is reclassified as compliant. If it does not, roadside enforcement personnel begin instituting graduated enforcement actions against the carrier. France is beginning a 3-year study to determine the effectiveness of this process.

In the United States, the Federal Motor Carrier Safety Administration uses a similar process when conducting safety inspections of carriers operating commercial vehicle fleets. The potential application of a process that includes commercial VSW violation patterns is in the early stages of discussion between FHWA and the Federal Motor Carrier Safety Administration.

Synthesis of Safety Implications of OS/OW Commercial Vehicles

In the United States, justification and authority for conducting VSW enforcement are vested in the public's interest in preserving infrastructure. The scan team observed the same principle in each of the countries visited.

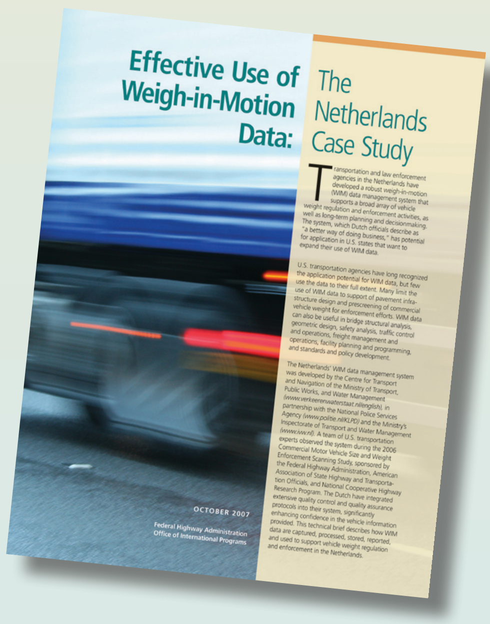
In addition, several of the countries identified safety as a primary motivator for VSW enforcement. In Belgium, officials have linked weight enforcement to the public's interest in safe operating conditions on highways. After years of collecting and analyzing weight and speed data, Belgian officials noted direct relationships between excessive speed by overweight vehicles involved in highway crashes and the frequency of fatalities. As a result, they were able to build the case to legislative leaders that weight and speed need to be regulated aggressively.

"Although public concerns about the impact of overweight vehicles on bridge and pavement conditions and on equitable trade practices are valid, the safety benefits tied to commercial vehicle weight enforcement need to be better defined [in the United States]," says FHWA's Nicholas. To understand the relationship between commercial motor vehicle weight condition and safety, researchers at The University of Alabama are preparing a white paper evaluating the availability of adequate data to articulate the safety aspects of conducting truck size and weight enforcement activities. The researchers presented their preliminary findings in a paper titled "Safety Implications of Truck Size and Weight Activities" at the 2008 International Conference on Weigh-in-Motion (ICWIM05)/Heavy Vehicle and Truck Technologies (HVTT10) Conference in Paris, France.

Use of WIM Data: Dutch Case Study

"The breadth of application potential for WIM data has long been recognized by U.S. transportation agencies," says Ric Athey, assistant director of Enforcement Services in the Motor Vehicle Division of Arizona DOT. "Few, however, are utilizing WIM data to its full extent, frequently limiting its application to support pavement infrastructure design and commercial vehicle weight enforcement activities through prescreening."

The Dutch have developed a robust WIM data management system that currently supports a broad array of vehicle weight regulation and enforcement activities, as well as long-term planning and decisionmaking activities, plus the conduct of special studies. They have integrated extensive quality control and quality assurance protocols into this WIM data management system, significantly enhancing confidence in the vehicle information provided.



In the United States, officials at State DOTs operate databases to manage highway and bridge programs and monitor travel to support program and policy development. To assist DOTs in extracting greater value from the databases, FHWA and AASHTO, supporting implementation of the scan findings, contracted the Texas Transportation Institute to prepare an informational brochure that documents the Netherlands' use of WIM data to support VSW management. The Netherlands' efforts include issuance of weekly data quality reports to enhance data confidence and integration of WIM data into long-term, aggressive planning goals related to reducing the number of overweight vehicles on the road. The six-page brochure, "Effective Use of Weigh-in-Motion Data: The Netherlands Case Study" (FHWA-PL-07-028) is available electronically at http://international.fhwa.dot.gov/links/pub_details.cfm?id=556. OIP distributed the brochure to State-level traffic monitoring and VSW enforcement personnel to help support implementation.

Where Do We Go From Here?

Next steps include defining specific timeframes, funding requirements, and sources for investigation or implementation of the remaining high-priority strategies.

Several companion activities currently are underway. FHWA is conducting a study to identify the use of best-practice technologies for commercial motor VSW enforcement in the United States and to develop a conceptual phased implementation plan modeled after the Lego™ or building block approach observed in the Netherlands for enhancing enforcement efficiency through technology. Technical assistance and consultation has been solicited from European experts met during the scan in the area of truck enforcement technologies, adding value and insight into the development and conduct of this FHWA-sponsored study titled *Truck Size and Weight*

The roadside signing indicates a downstream WIM and vehicle identification site in the Netherlands. *Photo: Hans van Saan, Dutch Ministry of Transport, Public Works, and Water Management.*

Enforcement Technology, being prepared by Cambridge Systematics, Inc.

Another effort, sponsored by NCHRP, involves outreach to State DOT executive-level staff to increase their awareness and support of integration of various implementation opportunities into their State programs. Presentations of key scan findings were made at the 2008 AASHTO annual meeting held in Hartford, CT. Site visits to a limited number of individual States for more detailed presentations on program enhancement opportunities associated with implementing scan findings will be scheduled as part of this effort.

The scan implementation team currently is planning a national brainstorm session on the role of WIM technology in truck enforcement programs over the short, medium, and long terms. "Creating overarching national support for automated truck weight enforcement, as was repeatedly seen in each of the European nations visited, is critical to a sustainable, coordinated national enforcement program that would benefit all States," says Athey. "Articulating the benefits of automated enforcement is crucial to this support; the brainstorm session will focus on energizing this effort."

Testing and research with B-WIM continues in Alabama and, more recently, in Connecticut. Alabama researchers continue to work with the Slovenian B-WIM System after hosting a B-WIM workshop in Birmingham, AL, in August 2008. Leading European B-WIM experts joined U.S. representatives at this workshop discussing B-WIM performance and areas of advancement in Europe with this technology.

Much was learned in Europe, and opportunities for the United States to improve its truck enforcement programs are progressing as a result of the scan. "The scan identified and recommended several European practices, technology applications, and procedures that have the greatest benefit for adaptation in the United States," says ODOT's Honefanger. "To further assess the practicality of implementation of the scan recommendations, several followup evaluations have been undertaken. The expectation is for vehicle size and weight programs for infrastructure preservation across the country to be radically enhanced and yet be better positioned to meet the growing needs of freight movement."

Jodi Carson is an associate research engineer with the Texas Transportation Institute. She has nearly 20 years of experience investigating various aspects of commercial motor VSW enforcement. Carson obtained a Ph.D. in civil engineering from the University of Washington and is a licensed P.E. in Montana and Texas.

Tom Kearney is a transportation specialist with FHWA and recently joined the Truck Size and Weight and Freight Operations and Technology Team in FHWA's Office of Operations. Previously, he was responsible for the New York State Truck Size and Weight Program for FHWA's New York Division. Kearney obtained an M.S. in regional planning from Albany State University.

For more information, see the scanning report at http://international.fhwa.dot.gov/links/pub_details.cfm?id=554 or contact Tom Kearney at 518-431-4125 or tom.kearney@fhwa.dot.gov.

Using CRFs To Improve Highway Safety

by Frank Gross and Karen Yunk

Crash reduction factors help identify the countermeasures with the most potential to save lives.

From 1993 through 2007, vehicle crashes on the Nation's roads claimed more than 40,000 lives annually. Despite efforts by Federal, State, and local transportation agencies, annual roadway fatality numbers—although decreasing gradually—remain stubbornly high.

In 2005, the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) established the Highway Safety Improvement Program (HSIP) as a core Federal Highway Administration (FHWA) program. The HSIP is structured to help transportation agencies at all levels reduce highway-related fatalities and serious injuries by promoting a strategic, data-driven process to identify, implement, and evaluate cost-effective roadway safety improvements.

For example, if a signalized intersection is experiencing a high number of left-turn crashes, which countermeasures do the data indicate should be considered? What is the likely improvement in safety for stabilizing a roadway shoulder? What change in the total number of crashes could be expected following implementation of various countermeasures to prevent roadway departures? Traffic engineers and other transportation professionals can find answers to these questions and more using crash reduction factors (CRFs).

A CRF is the percentage crash reduction that might be expected after implementing a given countermeasure at a specific site. For example, an agency installing centerline rumble strips on a two-lane road can expect, on average, a 14

(Above) Alabama widened the outside shoulder of this horizontal curve in Vinemont, added a guardrail, and installed rumble strips to enhance safety. CRFs can help decisionmakers identify the expected benefits of these countermeasures. *Photo: Dan Nabors, VHB.*

percent reduction in all crashes and a 55 percent reduction in head-on crashes, though engineers still need to apply sound judgment and consider site-specific environmental, traffic, geometric, and operational conditions that will affect the safety impact of a countermeasure. CRFs, therefore, support the data-driven process required by SAFETEA-LU by providing quantitative measures for estimating the safety effectiveness of potential roadway improvements.

FHWA and its partners have developed a variety of resources to promote use of CRFs in the transportation community. The resources include a desktop reference for using CRFs; three documents containing countermeasures targeting intersection, pedestrian, and roadway departure crashes; a CRF clearinghouse (in development); decisionmaking tools that use CRFs; and two training courses. These tools are discussed below, followed by an example of how one State is using CRFs to support its HSIP.

Online CRF Resources

With the click of a mouse, transportation professionals can access a comprehensive list of CRFs in the FHWA report *Desktop Reference for Crash Reduction Factors* (FHWA-SA-08-011). The report documents estimated crash reductions that might be expected when specific countermeasures or groups of countermeasures are implemented to prevent crashes involving intersections, roadway departures, and pedestrians. The *Desktop Reference* is a compilation of all CRF information available to date. Where applicable, it includes multiple CRFs for the same countermeasure, which enables engineers to review the range of potential effectiveness. The document lists CRFs not only for total crashes but also for specific crash types, such as head-on, rear-end, and angle, and specific crash severities, such as fatal, injury, and property damage only, to help identify the differential effects of countermeasures.

FHWA also developed four issue briefs that summarize the best available information on countermeasure effectiveness for intersection, pedestrian, and roadway departure crashes: *Traffic Signals*, *Toolbox of Countermeasures and Their Potential Effectiveness for Intersection Crashes*, *Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes* (FHWA-SA-07-014), and *Toolbox of Countermeasures and Their Potential Effectiveness for Roadway Departure Crashes* (FHWA-SA-07-013). All the documents are available online at http://safety.fhwa.dot.gov/tools/crf.

In addition, FHWA initiated development of an online clearinghouse to serve as a repository for CRFs and their supporting documentation. A search tool will help site users find the appropriate CRF to meet their needs. Transportation professionals will be able to submit their own CRFs to be included in the clearinghouse. FHWA expects the clearinghouse to be available in summer 2009 and updated regularly to reflect the ever-increasing knowledge base of published CRFs.

Decisionmaking Tools

The National Cooperative Highway Research Program (NCHRP) is undertaking a project (NCHRP 17-36) to produce the first edition of the *Highway Safety Manual* (HSM), expected to be available by the end of 2009, which will prominently feature CRFs. The HSM will contain the latest information and tools to facilitate roadway planning, design, operations, and maintenance decisions based on explicit consideration of the safety consequences. The HSM will feature a synthesis of validated highway research, procedures that are adapted and integrated into practice, and analytical tools for predicting impacts on road safety.

The HSM will use the phrases "accident modification factors" or "accident modification functions" (AMFs) when referring to CRFs. The main difference between a CRF and an AMF is that CRFs provide an estimate of the *percentage* reduction in crashes, while AMFs are a multiplicative factor used to compute the *expected number* of crashes after implementing a given improvement. Also, the AMFs included in the HSM were "filtered" from the available literature to include only information that is deemed reliable based on accuracy, precision, and stability.

Mathematically stated, an AMF = 1 – (CRF/100). Although CRFs and AMFs are simply different conventions for expressing safety effectiveness, CRFs and accident modification *factors* are constants; accident modification *functions* allow the factor to vary for different scenarios, such as for different traffic volume scenarios.

Two key safety analysis tools that are already available use CRFs and support implementation of the methodologies and procedures presented in the HSM. The tools help transportation professionals better understand the safety implications of their designs and decisions. The first is *SafetyAnalyst*, state-of-the-art software designed to help highway

This narrow, two-lane, rural road carries substantial truck traffic, as shown. Installing a shoulder could help enhance safety, and CRFs can help quantify the potential crash reduction benefit. *Photo: Dan Nabors, VHB.*

Dan Nabors, VHB

This two-lane, rural road in Alabama incorporates wide shoulders, shoulder rumble strips, a guardrail, and a relatively wide clear zone (the total roadside border area, starting at the edge of the traveled way, that is available for an errant driver to stop or regain control of a vehicle). Designers can use CRFs to help them understand the safety impacts of these design decisions.

agency decisionmakers develop a systemwide program for site-specific safety improvement projects. The other is the *Interactive Highway Safety Design Model* (IHSDM), a decision-support tool designed to help program managers, engineers, and other safety decisionmakers evaluate the operational effects of geometric design decisions. (See www.safetyanalyst.org and www.tfhrc.gov/safety/ihsdm/ihsdm.htm for more information.)

Each tool includes some form of CRFs; however, using the tools to their full potential requires an understanding of the fundamental concepts behind the CRFs. Toward that end, FHWA has developed two training courses on understanding and applying CRFs.

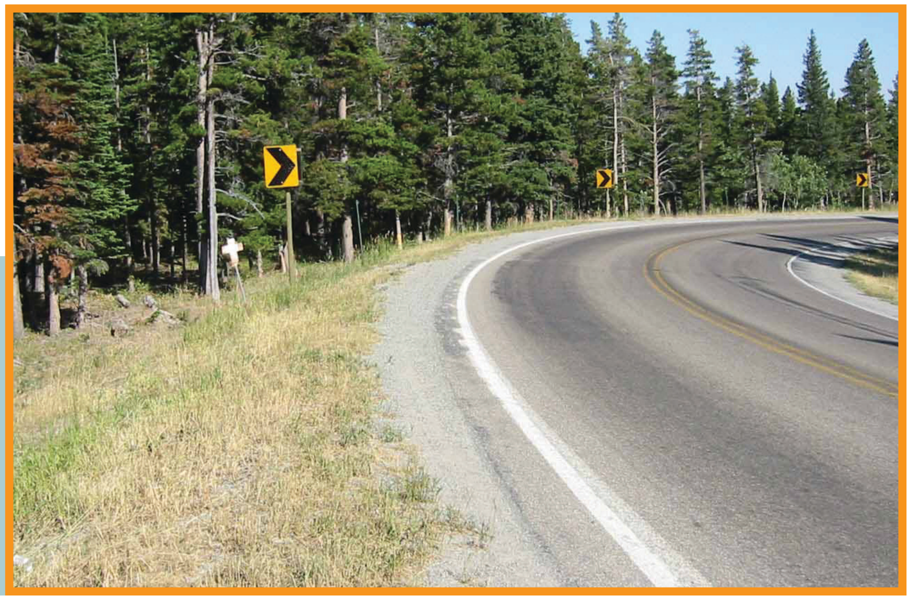
Training From NHI

Two Web-based training courses dealing with CRFs are available through the National Highway Institute (NHI): Application of Crash Reduction Factors (FHWA-NHI-380093) and Science of Crash Reduction Factors (FHWA-NHI-380094). Together, they respond to a clear need for formal training and provide basic knowledge on CRFs.

The Application of Crash Reduction Factors course helps safety professionals select the appropriate solutions to specific highway safety problems. Content focuses on CRF background, terminology, and components and how to diagnose safety issues, identify and select potential countermeasures, and compare their anticipated effectiveness. Instructors demonstrate critical points through case studies targeting intersection, pedestrian, and roadway departure crashes.

The course Science of Crash Reduction Factors helps participants learn to critically assess the quality of CRFs by understanding how safety is measured and the statistics and methodologies that form the basis of CRFs. Participants leave the course with a checklist they can use to determine the quality of a CRF and its applicability to their particular situations.

Each course is approximately 2 hours long and blends self-study and online instructor-led portions, which promote frequent interaction among participants and instructors. Case studies and practical exercises help transportation professionals build skills and confidence in applying CRFs, determining the quality and



Crews installed chevron signs to enhance warning along this sharp horizontal curve with narrow shoulders. But how effective are the signs? How cost effective would it be to install a shoulder along the outside of the curve? Using CRFs, engineers can quantify the anticipated safety effects of geometric design improvements.

Ohio installed left- and right-turn lanes at this unsignalized rural intersection. The sight distance is limited due to a vertical curve near the intersection, which might have resulted in rear-end crashes. Two new NHI courses explain how to diagnose safety issues like this and apply CRFs to explore the safety effects of potential countermeasures.

applicability of a CRF, and selecting appropriate safety measures.

Both courses are designed to benefit those who select, plan, design, maintain, and research safety-related highway improvements. Upon successful completion of each course, including a passing score on the final exams, participants receive professional development credits in the form of continuing education units.

Participants can register individually for prescheduled offerings, or a State department of transportation (DOT) might decide to host one of the courses for its own personnel, similar to traditional classroom training sessions. This flexibility through NHI ensures that agencies at different levels of government (local, regional, or metropolitan area) and consultants can participate.

CRFs in Practice

NHI piloted both courses in fall 2008, and participants reported positive feedback on the content and delivery. G. Stuart Thompson, a highway safety engineer with the New Hampshire Department of Transportation (NHDOT), participated in both CRF pilot training sessions. He had become familiar with CRFs when he served as assistant director of the Utah Local Technical Assistance Program (LTAP).

"The Utah DOT was using CRFs, so we incorporated them into an LTAP training course we were developing," Thompson says. "Since joining NHDOT, I've used CRFs to develop our '5 Percent Reports' [SAFETEA-LU requires States to identify no less than 5 percent of locations exhibiting the most severe safety needs] and in conjunction with some road safety audits we conduct." Thompson says he believes that the more engineers work with CRFs, the more comfortable they become with the process of using them.

"The important thing I learned from the courses is not to piggyback CRFs, something I was unaware of," he says. Thompson underscores an important point: CRFs should not be combined without extreme caution.

If multiple countermeasures are implemented at one location, then common practice is to multiply the CRFs, or more specifically their alternative form, AMFs, to estimate the combined effect of the countermeasures. In fact, there is limited research documenting the combined effect of multiple countermeasures. Although implementing several countermeasures might be more effective than just one, it is unlikely the full effect of each countermeasure would be realized when they are implemented concurrently, particularly if the countermeasures are targeting the same crash type.

Because multiplying several CRFs is likely to overestimate the combined effect, FHWA recommends exercising engineering judgment when estimating the effectiveness of multiple countermeasures. A more appropriate method for estimating the combined effects of multiple countermeasures is to conduct a rigorous before and after evaluation of several locations where the specific combination was implemented.

New Jersey's Experience

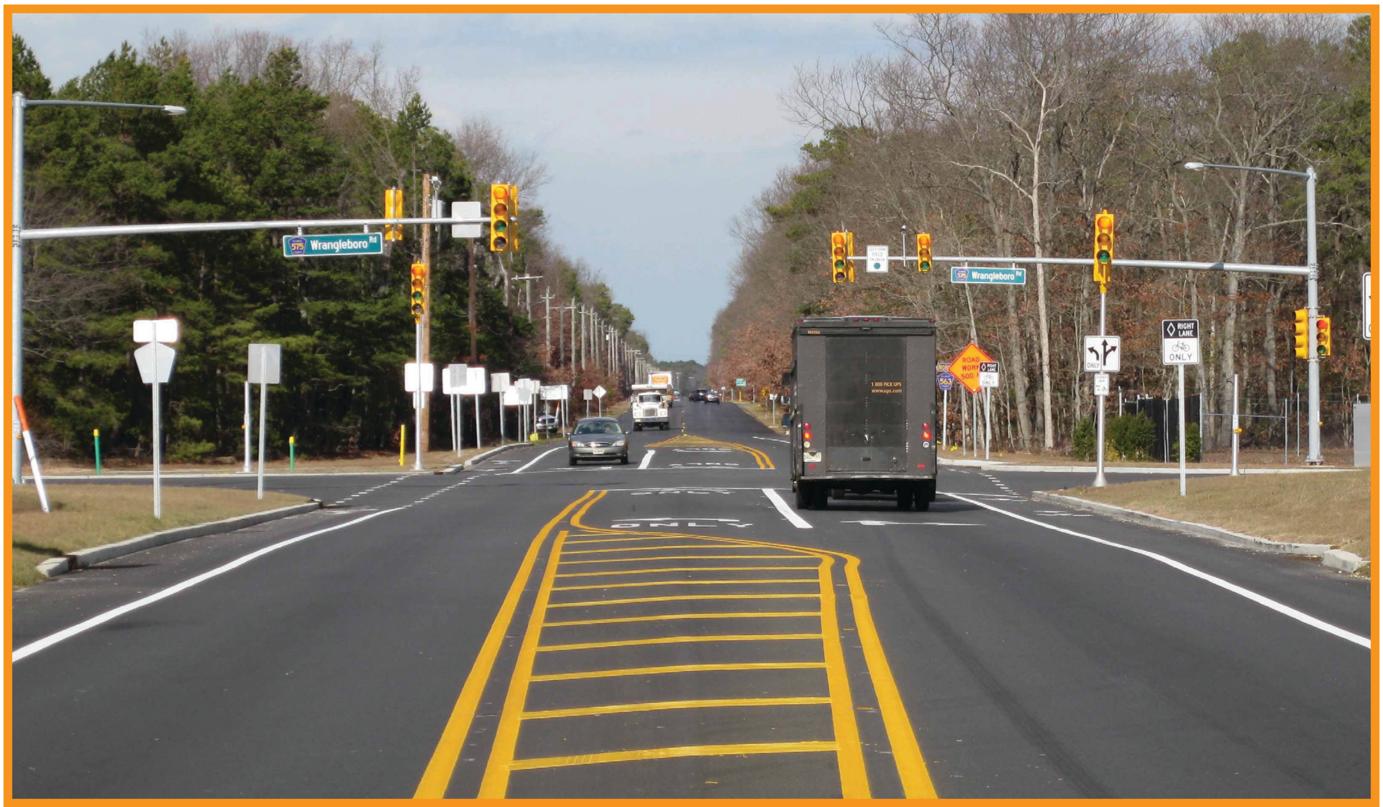
The New Jersey Department of Transportation (NJDOT) has long recognized the importance of CRFs in conducting benefit/cost analyses for highway safety improvements. The NJDOT Crash Analysis and Safety Program Development Section, within the Bureau of Safety Programs, applies a data-driven decisionmaking process to select CRFs for proposed safety countermeasures.

For example, a project to improve the safety of an intersection typically involves a detailed review of individual crash types (rear-end, right-angle, left-turn, pedestrian, etc.), including a review of summary data on intersection crashes and individual police reports.

From this review, the analysis and project development team develops a benefit/cost worksheet. The worksheet helps engineers determine the expected cost-effectiveness of selected countermeasures derived from typical quick-fix treatments such as improved signing, striping, signal layout and operation, and minor geometric/curb and sidewalk work.

Engineers use CRFs to calculate the net benefit included in the benefit/cost ratio. (Note that some treatments might reduce specific crash types or severities while increasing others. A classic example is installing a traffic signal, which might reduce right-angle crashes but increase rear-end crashes.) The benefit/cost ratio helps justify and prioritize funding for safety projects as part of New Jersey's HSIP.

According to Kevin Conover, the project engineer who leads the Crash Analysis and Safety Program



Atlantic County, NJ, used CRFs to select a combination of safety improvements to reduce right-angle and same-direction crashes at the intersection (above) of Tilton Road (County Route 563) and Wrangleboro Road (County Route 575). The reconstructed intersection (below) includes left-turn lanes on all four approaches, bike lanes, and signal timing modifications. *Photo: John A. Masi, Atlantic County, NJ, Division of Engineering, Department of Regional Planning & Development.*

Development Section, NJDOT engineers research historical data and review available technical briefing sheets, including CRF data from other States. As a result of these efforts, Conover says, NJDOT engineers are gaining confidence in identifying and applying CRFs.

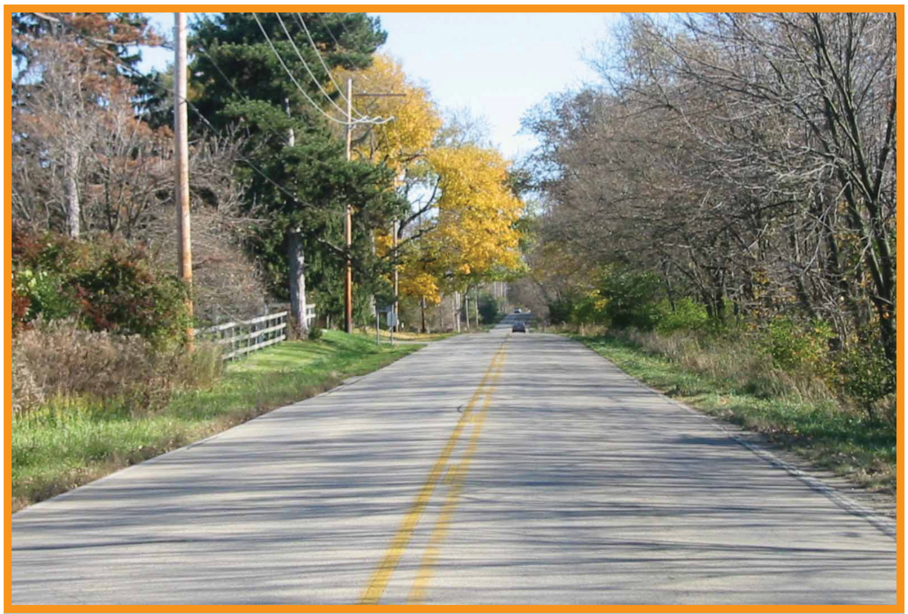
Evaluating completed projects and achieving or exceeding expected reductions in the frequency and severity of targeted crash types also helps boost confidence in the effectiveness of CRFs. However, the problem remains that some crash countermeasures do not have CRF data, or historical evidence for their application in combination with multiple countermeasures is lacking.

"Using CRFs helps us determine whether a small-scale safety project will be cost effective and helps us elevate the priority of larger scale capital projects," Conover says. "Through postproject implementation analysis, we also will find out if the safety factor expected was ultimately realized. That is one of our checks for success, but the bottom line is data. Every successful project begins by studying the data to help us understand what the numbers really mean. We have to distinguish between the real and perceived safety problems and allow for a certain amount of random, incidental events and driver error."

What Was Old Is New Again

As many transportation safety professionals may know, CRFs are not a recent innovation. States have included safety analysis and cost information factors in project decisions for years. CRF resources, such as the *Desktop Reference*, *Toolbox of Countermeasures* documents, and the forthcoming clearinghouse, consolidate the latest CRF-related information into one place. Engineers and other project personnel no longer need to spend time searching for CRF data in a variety of publications housed in disparate offices; the information now is readily available in a central location on the Web.

Rudolph Umbs, a senior highway safety engineer at the FHWA Resource Center, is a longtime trainer and advocate for innovative highway safety practices. He participated in both online CRF pilot sessions for the NHI courses. "Whether attendees are experienced FHWA safety professionals or new to engineering, the CRF courses provide a refresher to the concept of crash reduction factors and how to use them," Umbs says. "The courses are a way for highway professionals to stay connected and have a better perspective on how they can use limited safety funds to their highest effect."

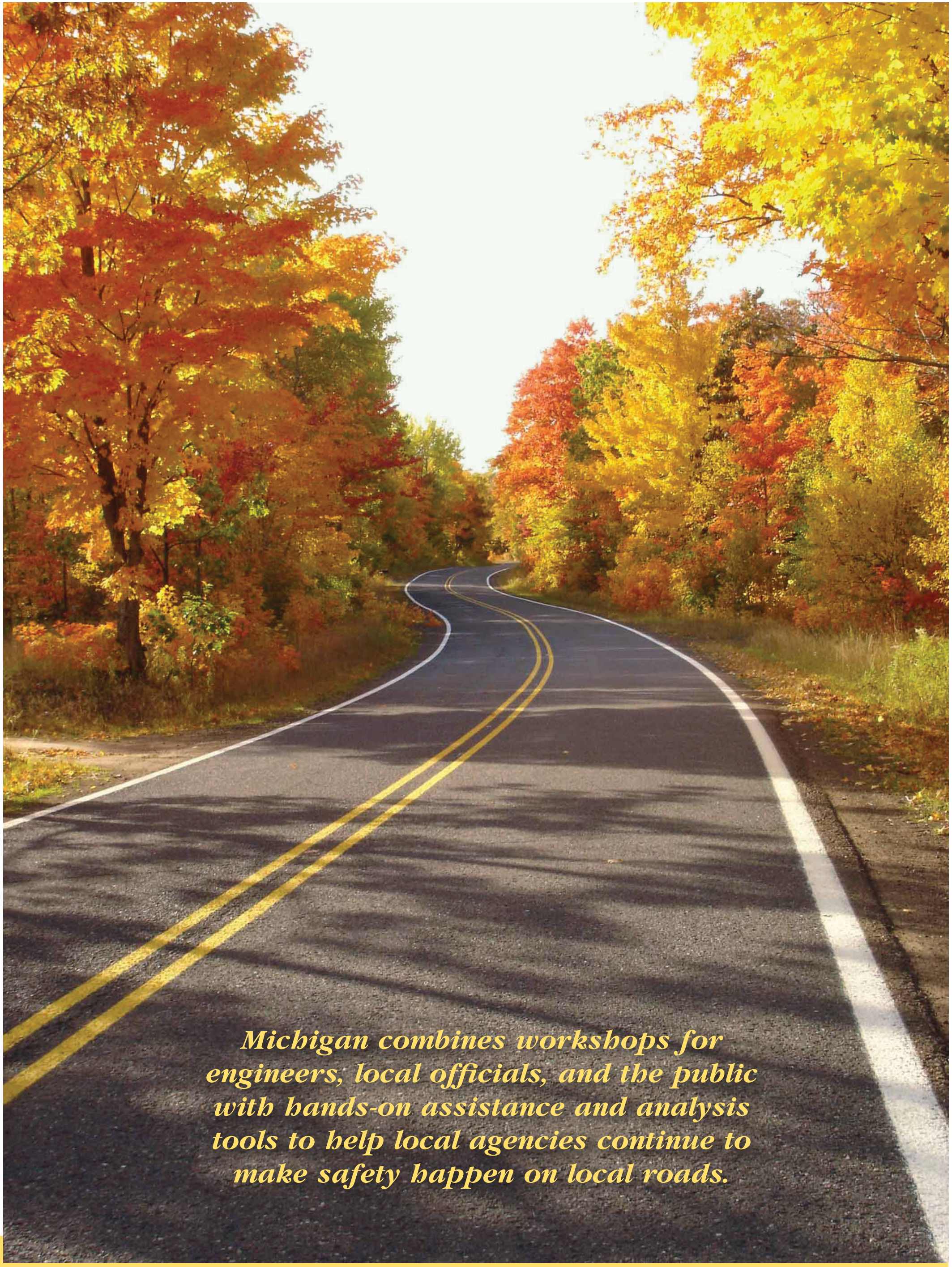


This narrow, two-lane, rural road has centerline pavement markings, but no edgeline markings and a limited shoulder. As explained in the NHI courses, CRFs can help engineers identify the potential benefits of pavement markings and wider shoulders and apply CRFs to compare alternative treatments.

Frank Gross, Ph.D., P.E., is a highway safety engineer at Vanasse Hangen Brustlin, Inc. (VHB). He has more than 7 years of experience in transportation research and engineering and as a highway safety researcher. He has experience in highway design, traffic operations, and construction inspection. As a safety researcher, Gross specializes in highway safety evaluations, data analysis, and road safety audits. He was involved with a Transportation Research Board task force to develop core competencies for the highway safety workforce. He earned a Ph.D. in civil engineering from The Pennsylvania State University, where he specialized in transportation safety. He also earned a graduate minor in statistics.

Karen Yunk, P.E., is a transportation specialist with the FHWA Office of Safety. Her primary duties involve promoting decisionmaking tools that support HSIP-related activities. Before joining the Office of Safety, Yunk served as the traffic operations and safety engineer in the FHWA New Jersey Division Office. In this capacity, she managed the Federal safety program and provided technical expertise on a variety of transportation safety-related topics. Previously, she worked as a transportation planning and traffic engineering consultant. Yunk holds both bachelor's and master's degrees in civil engineering from Rutgers, The State University of New Jersey. She is a registered professional engineer in New Jersey.

For course information, or to register for the CRF courses Application of Crash Reduction Factors and Science of Crash Reduction Factors, visit the NHI course catalog at www.nhi.fhwa.dot.gov. For information regarding CRF resources, contact Karen Yunk at 609–637–4207 or karen.yunk@dot.gov.



Michigan combines workshops for engineers, local officials, and the public with hands-on assistance and analysis tools to help local agencies continue to make safety happen on local roads.

Traffic Safety Education for Nonengineers

by Terance L. McNinch and Timothy K. Colling

Every year, thousands of news headlines report fatalities and serious injuries on the Nation's highways. Managing a transportation network, and in particular maintaining safety on roadways, has serious implications for families, society, and the economy. Therefore, the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) of 2005 renewed emphasis on traffic safety as a national priority and thus as a priority for the Federal Highway Administration (FHWA) and State and local departments of transportation (DOTs).

A disproportionately large number of severe and fatal crashes occur on the 3 million miles (4.8 million kilometers) of local roads, which represent 75 percent of the Nation's total network. More than 38,000 counties, cities, villages, towns, and tribal governments manage those local roads.

According to Larry Tibbits, recently retired chief operations officer at the Michigan Department of Transportation (MDOT), "Although national data are difficult to pin down, MDOT has concluded that, for any given year, approximately 60 percent of all crashes in Michigan occur on roads owned and operated by local government jurisdictions. These roads carry only about 50 percent of the [State's total] traffic. If we are going to make a significant reduction in traffic crashes, fatalities, and injuries, we can't just focus on the State routes; we have to provide traffic safety resources and support to local agencies."

Reducing the high crash rate on local roads is complicated by the fact that local agency engineers, administrators, and elected officials are faced with dozens of other public works priorities demanding their attention. And few agencies possess the technical resources to get the traffic safety job done. "The majority of those 38,000 local agencies lack the necessary expertise, the data, and the tools to conduct effective traffic safety analysis," says Executive Director Tony Giancola, P.E., of the

(Above, left) Rural roads like this one in Michigan account for a higher number of crashes than would be expected from the volume of traffic they carry. *Photo: Terance L. McNinch, Michigan LTAP.*

National Association of County Engineers (NACE). "Making traffic safety happen on the local level requires that professional road managers are trained to conduct traffic safety analysis and learn how to communicate traffic safety principles to the nontechnical community."

Too often, local elected officials and the public exacerbate the traffic safety problems they hope to solve. "Many county engineers [and] professional road managers have a story to tell about how the lack of technical understanding by the nonengineering community distorted, derailed, or totally disregarded a technically sound traffic engineering solution he or she developed," says Giancola. This situation is the result of professionals failing to view education of the nonengineering community as a core requirement in accomplishing their goals.

In recent years, MDOT has partnered with Michigan's Local Technical Assistance Program (LTAP) to address these needs through a series of workshops designed and conducted specifically for technical and nontechnical audiences. Other tools used by MDOT and LTAP involve making location-specific traffic crash data available to local transportation agencies, plus sophisticated data analysis tools and hands-on technical assistance that not only solve problems but also educate local agency personnel in the traffic safety process so they can solve their own problems in the future. These efforts could not accomplish Michigan's traffic safety goals in and of themselves. Together, they form a multifaceted approach that provides a traffic safety payoff greater than the sum of the individual parts.

Michigan has a long history of such efforts, many funded by the Michigan State Police Office of Highway Safety Planning. A number of outreach efforts took place starting in the 1970s through the 1990s, plus site-specific safety projects and MDOT analytic assistance to local agencies. Adapting new technological options may have helped attract new attention to those safety and local assistance efforts, as has staff turnover and other factors, ultimately leading to the development of the workshops.

Michigan's local roads and statewide MDOT roads have enjoyed a sustained decline in crashes, fatalities, and injuries over the past 16 years. Statewide fatalities in 2008 dropped to the lowest level since 1925. With this excellent safety track record, measuring progress that can be attributed to these more recent local safety initiatives may be difficult. But the high level of participation and interest by both the engineering and nonengineering communities would seem to indicate that traffic safety on the local system will continue to improve over coming years as the positive effects of these countermeasures and treatments are realized.

Counterintuitive Solutions Versus Gut Instincts

Many concepts in traffic safety engineering are counterintuitive to conventional wisdom. For example, gut instinct may lead a person without a technical background to believe that installing stop signs at every intersection along a route will slow the speed of traffic. But according to "Neighborhood Speed Control—U.S. Practices," an article published by the Institute of Transportation Engineers (ITE), and reports by FHWA, the Transportation Research Board (TRB), and others, the opposite is true, and installing unwarranted stop signs actually can increase midblock running speeds.

"The public doesn't see the interrelated factors that influence traffic safety decisions," says Dale Lighthizer, Ph.D., P.E., safety programs section manager, MDOT Division of Operations. Road geometry, pavement surface condition, traffic volume, traffic turning movements, and driver visual acuity, aggressiveness, reaction time, and attitude are all factors that influence traffic safety decisions. And the public may be unaware of the tradeoffs needed among these factors. "This lack of understanding leads the public to think that quick remedies can solve every traffic safety problem," says Lighthizer. "They often say, 'It's obvious what the problem is; just fix it.' But traffic safety doesn't work that way."

Considering the technical challenges and nonintuitive nature of the traffic safety field, members of the public sometimes have difficulty accepting the recommendations of a traffic safety engineer. That understanding can be acquired only through a nontechnical explanation of the solution—something engineers and other transportation professionals are not reputed to provide. Many engineers do not view public communication as a function of their job, and as a result often they are typecast as poor communicators, deterring elected officials and the public from asking questions in the first place. Engineers easily delude themselves into thinking that because the solution proposed is technically superior to all other options, elected officials and the public will accept it automatically as the best solution too.

Technical assistance by Michigan's Local Technical Assistance Program (LTAP) and MDOT's Local Safety Initiative (LSI) has prompted innovative treatments such as the recessed pavement marking being placed by this worker after embankment improvements on a curve near Lake Odessa, MI. The recessed marking improves traffic safety by maintaining visibility during inclement weather.

Thomas J. Morgan, IV, Ionia CRC

Wayne A. Schoonover, P.E., Ionia CRC

The recovery zone on this advisory speed curve—20 miles per hour, mi/h (32 kilometers per hour, km/h)—outside Lake Odessa, MI, was steeply sloped with a dense tree line. After MDOT's Local Safety Initiative review, the Ionia County Road Commission flattened the slope, cleared back the trees, added chevrons, and upgraded existing engineering grade signs to high-intensity prismatic signs to better alert drivers of the approaching curve.

Providing knowledge of technical issues in both technical and nontechnical language can help the public better understand safety needs. Some people might desire to hear either, or both, of the technical and nontechnical explanations.

Achieving a Common Sense Approach to Local Traffic Safety Education

Staff members of Michigan's Local Technical Assistance Program (LTAP) developed instructional materials, *Common Sense Solutions for Intersection Safety Problems*, for dissemination in 2005. The development of these materials was in addition to the 2004 core annual work program activities that the LTAP center typically performs. To get this initiative off the ground, additional funding sources were needed. Approximately half of the development funds came from a combination of a competitive grant (FHWA Technology Transfer and Innovation Program) and FHWA Office of Safety funding sources. The remainder came out of the 2004 Michigan LTAP budget.

The training materials target the nonengineering community, such as local elected and appointed officials, agency managers, law enforcement personnel, school administrators, and the public. The objective of the material is to provide nontechnical explanations about the technical aspects of intersection traffic safety. The training materials were distributed to every LTAP and Tribal Technical Assistance Program (TTAP) center in the United States.

During 2005 and 2006, the Michigan LTAP conducted a series of 1-day training workshops on traffic safety issues at intersections at 19 locations in Michigan to audiences that totaled more than 450 participants from local governments. Of these, 91 percent were nontechnical personnel. The Michigan State Police Office of Highway Safety Planning provided workshop fee scholarships to any nonengineer participants, thereby eliminating financial barriers to attendance.

The training materials consist of 12 modules, each approximately 1-hour long and covering the following topics: Evolution of an Intersection, Geometric Flaws, Sight Triangles, Pedestrians, Signals, Signs, Red Light Running, Roundabouts, Crash Data, Crash Statistics, Road Safety Studies, and Where to Get Help. The instructional material's nonlinear format enables workshop hosts to mix and match the modules, depending on the needs of the audience.

The participant handout that comes with the modules includes summaries that contain the key points covered in the presentations. Also included are references to additional resources with day-to-day usefulness, such as the *Manual on Uniform Control Devices* (MUTCD) sections on stop sign placement and signal warrants, research papers on the negative impacts of stop signs used as speed control, traffic calming techniques, and geometric guidelines for intersections in the American Association of State Highway and Transportation Officials' (AASHTO) *A Policy on the Geometric Design of Highways and Streets* (the Green Book).

Nontechnical audiences quickly lose interest in technical training if the material is not presented at a basic level or if it uses excessive technical jargon. When developing the materials, the LTAP staff paid close attention to the use of nontechnical language and provided explanations for technical concepts.

Targeting Audiences

The Michigan LTAP originally titled the training workshop, Intersection Safety for Non-Engineers. While preparing to hold two pilot sessions, the Michigan LTAP had difficulty attracting participation—to the point where the sessions had to be canceled. In an attempt to understand the problem, LTAP staff conducted telephone interviews with a cross section of the target audience who had been mailed the promotional flyer. Some of the people interviewed indicated that they believed the training would be too technical for them because the word "engineer" appeared in the title.

According to Christine Codere, Michigan LTAP office manager, one respondent stated, "Intersection Safety for Non-Engineers. I'm not an engineer, so why would I attend?" Codere adds, "We were all a bit perplexed. The title seemed clear to us. But clear to us isn't what matters." The LTAP staff put their heads

Wayne A. Schoonover, P.E., Ionia CRC

The westbound sight distance around this curve near Saranac, MI, is blocked by the crest in the road and an embankment with vegetation on the right—limiting a driver's decision time before turning left or pulling out into traffic from the side road. A convenience store, located just out of view on the right, contributes to traffic entering the travel lane.

together and renamed the workshop and the corresponding publication, *Common Sense Solutions for Intersection Safety Problems*.

Several agencies also commented that they did not think the training was targeted at their employees. Codere recalls, "One law enforcement officer said that he gets so much mail, if the flyer doesn't say 'For Law Enforcement' on the cover, he doesn't even open it. It goes in the trash."

To counter this reaction, the Michigan LTAP customized the front cover of the workshop flyer for each target group. Law enforcement agencies received a flyer titled "Common Sense Solutions for Intersection Safety—A workshop for law enforcement agencies." Other titles targeted the public and elected and appointed officials in townships, cities, and villages.

LTAP staff also modified the training agenda to replace engineering terms with phrases that more closely relate to the audience's understanding of the topic in their day-to-day experience. Some examples include the following: The Michigan LTAP changed "Sign Design and Placement" to "Signs—Do it Right or Pay the Price!" Similarly, "Crash Statistics" became "Most Bad Accidents Happen on YOUR Roads!" And "Introduction to Roundabouts" turned into "Roundabouts—Take a Deep Breath, Don't Panic." And "Partnering on Traffic Safety Issues" was changed to "You're Not Alone—Getting Others to Help."

The Michigan LTAP sent the modified flyer to the same list of people who had received the first mailing. This step turned out to be the key to success. The response rate of the second mailing matched the rate that the Michigan LTAP normally receives in response to other flyers. Sending the right message to the right audience generated active participation.

Using Champions to Help Fill the Room

As the Michigan LTAP discovered, attracting a nontechnical audience for traffic safety training is a challenge. First, as with other types of education, the people who most need to attend are least likely to attend. Second, local officials have dozens of

Wayne A. Schoonover, P.E., Ionia CRC

After an LSI review, the Ionia CRC lowered the road crest to increase stopping sight distance and removed the bank within the right-of-way. A geosynthetic embankment system was used to stabilize the slope because the property owner would not grant access for further grading of the bank. An island now separates the convenience store parking lot (out of view on the right) from the roadway.

Wayne A. Schoonover, P.E., Ionia CRC

The eastbound sight distance around the same curve near Saranac, MI, is blocked by the embankment and crested roadway, hiding the approaching intersection and the convenience store parking lot.

priorities demanding their attention, and traffic safety may not be high on the list—unless a traffic safety crisis currently happens to be headline news. Third, the audience that the Michigan LTAP was pursuing for this training was not its typical engineering audience—a group with whom LTAP has an established reputation.

LTAP staff decided to recruit local champions to help attract the target audience. The champion (often, but not always, a county engineer) recruited secondary contacts (known local traffic safety advocates) to promote the training communitywide. Asking these local advocates to recruit their peers made all the difference because this approach avoided the baggage that often exists between transportation professionals and communities.

In addition, LTAP partnered with the Michigan Municipal League (MML), the County Road Association of Michigan (CRAM), and the Michigan Townships Association (MTA) to reach the membership of those organizations directly.

Applying Common Sense In Saginaw County

Saginaw County is located in southeastern Michigan. With a population of 202,000 in 2007, the county is a mix of urban areas (10 cities) and rural/agricultural areas. The county road commission is responsible for maintaining 1,846 miles (2,971 kilometers) of county primary and local township roads. The rural areas are under intense development pressure with farmland being converted to residential use. Roads that previously were adequate to serve a small number of farms quickly become insufficient when serving several hundred newly constructed residences.

Now-retired Saginaw County Highway Engineer James Lehman, P.E., faced strong public reaction following a series of serious injury and fatal crashes that occurred during 2003 and 2004. His investigation indicated that, in the majority of cases, the crashes were not correctable through any type of engineering action and that the actions demanded by the public could result in new, unsafe conditions. His findings were not received well. He felt the public assumed that his decision was influenced by an ulterior motive, such as an attempt to save money or that he just wasn't concerned about the problem. But he knew that neither was true.

In an effort to ease some of the political tension and provide Saginaw County's elected officials with a better understanding of the technical issues involved in solving traffic safety problems, Lehman contacted the Michigan LTAP with a request to conduct the Common Sense Solutions for Intersection Safety Problems training. "For years we have taken advantage of the training, crash data, and RoadSoft tools provided by [Michigan] LTAP in our safety work," says Lehman, "so I trusted this training session could alleviate some of the tension in the air."

Lehman adds, "The training was a lively event. During the morning session, one individual in particular took a really combative stance, challenging everything LTAP instructor Tim Colling had to say. But Tim engaged him, using it as a way to bring the other participants into the discussion and highlight the counterintuitive nature of traffic safety."

As the session progressed, the combative participant continued to press his challenges. "By the afternoon, rather than Tim confronting the challenges from the combative participant, the other participants were confronting him, using their newfound understanding to guide the discussion. This clearly demonstrated to me the effectiveness of the material and the instructor. Unfortunately, at the end of the day, this guy still refused to consider any approach but his own. But the rest of the participants left the training with an appreciation of the complexity of what I was trying to deal with."

Several weeks after the training, Lehman reported that he had received positive feedback from local officials who had attended. He noted a marked change in their attitude and an openness to accept his agency's engineering guidance. According to Lehman, "Even though it was the same story I had been telling them for years, bringing in an instructor with no perceived vested interest and providing explanations designed specifically for a nontechnical audience really made a difference."

Educating Elected Officials And Nontechnical Staff

Although the vast majority of participants attending the Common Sense

Solutions for Intersection Safety Problems workshops are nonengineers, only a relatively small number are elected or appointed officials—the ultimate decisionmakers. To reach that audience, the Michigan LTAP decided to take a different approach: condense the *Common Sense Solutions* materials to fit into a morning workshop format and market it directly to elected and appointed officials by partnering again with MML, CRAM, and MTA.

In an attempt to give the training a twist that would grab the officials' attention, the LTAP staff settled on the title, Elected Officials: What YOU Need to Know About Traffic Safety (And What YOUR Constituents Expect YOU to Know!). The course's material centered around the fact that seat-of-the-pants solutions often make the situation worse and that by tapping into the technical expertise of their professional staff, these elected officials could make informed decisions that would be good for their constituents and hence good for them too.

Registration for four sessions held in December 2008 exceeded the room capacity at three locations. Unfortunately, a blizzard that swept across the Midwest that week put a dent in the attendance, but the workshops were held nonetheless. The participant discussions that took place during the sessions confirmed to the LTAP staff that local government officials want to make informed decisions, but technical concepts just need to be explained at their level and in the context of their experience.

LTAP staff tried some innovative approaches to dovetail the workshop's content with real-life situations experienced by local officials. Requests for stop signs as a speed reduction measure are a classic case of a misguided countermeasure. As noted previously, unwarranted stop signs actually can increase between-block speeds. Public misunderstanding keeps the requests coming in and all too often is supported by elected officials who demand their installation. "The instructor used a prerecorded fictional telephone conversation between a resident and a mayor about installing a stop sign on her busy street in order to slow traffic," says Phil Karwat, city engineer for Saginaw, MI. "The mayor goes on to call the Department of Public Works superintendent with the command to get the signs installed. Everyone in the room has gotten these calls, so it really hit home. Most of the participants actually thought the call was real." This technique was intended to get participants to sit up and take notice—and they did.

The technical staff who attended saw firsthand some techniques they can use at their agencies to better communicate the technical concepts of traffic safety. Many of the elected officials also walked away from the session with newfound understanding. "As an elected official in a small village, I am confronted with making decisions far outside my personal expertise," says Carl Hamann, councilman for Sanford, MI. "At the workshop for elected officials, I discovered that everything I thought I knew about traffic safety was incorrect. That was an eye-opener." At the next village council meeting, Hamann gave a short presentation about what he had learned, which led to a discussion about decisions the council had made in the past. "We came to the realization that we really do need to consult with professionals when making these types of decisions," he said. "Keeping our communities safe is a priority." This viral effect—moving the message out through the community—is what the Michigan LTAP hoped would happen.

Sharing Safety Expertise With Local Agencies

Another approach MDOT uses is its Local Safety Initiative (LSI). This voluntary program provides local agencies with the services of a skilled MDOT traffic safety engineer in an effort to reduce fatal and serious injury crashes on the local road network. The program takes a "teach them to fish" approach to traffic safety by not just providing a service as a handout, but rather by working with the local agency engineer—peer to peer—to pass on the skills necessary to conduct traffic safety studies in-house.

An important component is MDOT's provision of the analysis results to the local agency, and only that agency, without publicizing the data. This aspect is key in that it mitigates any fear by the participating agency of unreasonable expectations on the part of the public. "When I invited the LSI staff to Ionia County to do their safety assessment on our county and local roads, I did

The improvement shown here allows oncoming traffic to be seen, as well as a portion of the convenience store, thereby alerting drivers to what is ahead. After the vertical crest curve was cut, the previous stopping sight distance was allowed to increase.

Wayne A. Schoonover, P.E., Ionia CRC

so with cautious optimism," says Wayne A. Schoonover, P.E., county highway engineer with the Ionia County Road Commission (CRC). "I hoped to take advantage of skilled, professional resources, but expected little of the outcome. I kept asking myself: What if the results ended up with a list of problems we aren't able to solve? I didn't want to spread false hope to the public and put the road commission in a bad situation."

The LSI staff begins by reviewing with the local agency how the process works. "Intersection analysis typically begins by looking for trends in crash data over the past 5 years," says Tracie Leix, engineer manager with the MDOT Safety Programs Unit. "We use the safety module in RoadSoft to do intersection ranking and a summary of total crashes. We also search for locations that meet the criteria for High Risk Rural Roads [HRRR] funding. Many agencies don't realize that they have locations that qualify." The LSI staff verifies the reports using digital copies of the UD-10 traffic crash report directly accessible through RoadSoft. The process is repeated for each road segment.

Next, LSI staff members join local agency staff for site reviews on the locations of interest. During the review, LSI staff members make suggestions, both engineering and nonengineering, with a focus on low-cost treatments. "All the suggestions are made in conversation or with a brief summary," says Lighthizer. "There are no formal reports. It's up to the local agency to take action if they feel a suggestion is justified, and they have the funds. We have found that this approach has helped to build trust in our relationships with the local agencies."

The LSI staff also can help the agency identify funding sources and complete their applications for HRRR funding. For several locations, Michigan safety funding has been provided through LSI. In those cases, as in HRRR projects, MDOT will conduct a 3-year, before-and-after study to document the performance of the treatments. "Nationwide, there is a great need to document the cost effectiveness of low-cost treatments," says Lighthizer.

Ionia County's Schoonover reports that the LSI staff confirmed many locations of safety concern that were already on his radar, but more important, some locations that were not. "Improvements at the Grand River-Morrison and Vedder-Tasker intersections are a direct result of working with LSI and educating myself on how to use RoadSoft to conduct traffic safety analyses," he says. "It's a great example of how a local agency can work with LTAP and the State DOT to make roads safer."

To date, the LSI program has collaborated with 51 local agencies, with another 13 agencies waiting in the queue.

The Art and Science Of Traffic Safety

Another need at the local level is education on the latest tools and techniques for analyzing traffic safety. Traffic safety analysis draws from a number of professional areas, including civil engineering, epidemiology, human behavioral science, and forensics. Professor Emeritus Ezra Hauer, of the University of Toronto and a renowned expert in the application of engineering principles to traffic safety, wrote in the *Transportation Research Record* that this kind of analysis is "akin to a process of medical diagnosis, with perhaps a keener awareness of costs and budgets."

Successful traffic engineers usually devote several years to practical experience beyond a formal college education to become effective at making decisions regarding traffic safety improvements. But local agency engineers may not have that experience. Fortunately, advances in computing technology have simplified the lengthy manual effort previously required, such as mass sorting paper crash reports and hand plotting dozens of data elements per record in an attempt to find a common element that provides clues to a potential causal factor. But the need remains to train these practicing engineers in the "art" of traffic safety analysis. "Most of our local agencies have never received specific education in safety analysis, and it appears that this is the situation nationwide," says Jason Nordberg, senior planner, Genesee County Metropolitan Planning Commission. "The only solution is training."

The Michigan LTAP developed material for a 1-day workshop specifically for local agency engineers and technical staff, titled Traffic Safety Analysis—From Finding the Problem to Fixing It. In July 2008, Michigan LTAP held four sessions statewide. Participants used their own laptop computers, the safety module in Michigan's RoadSoft software, and 10 years of crash data from each participant's agency.

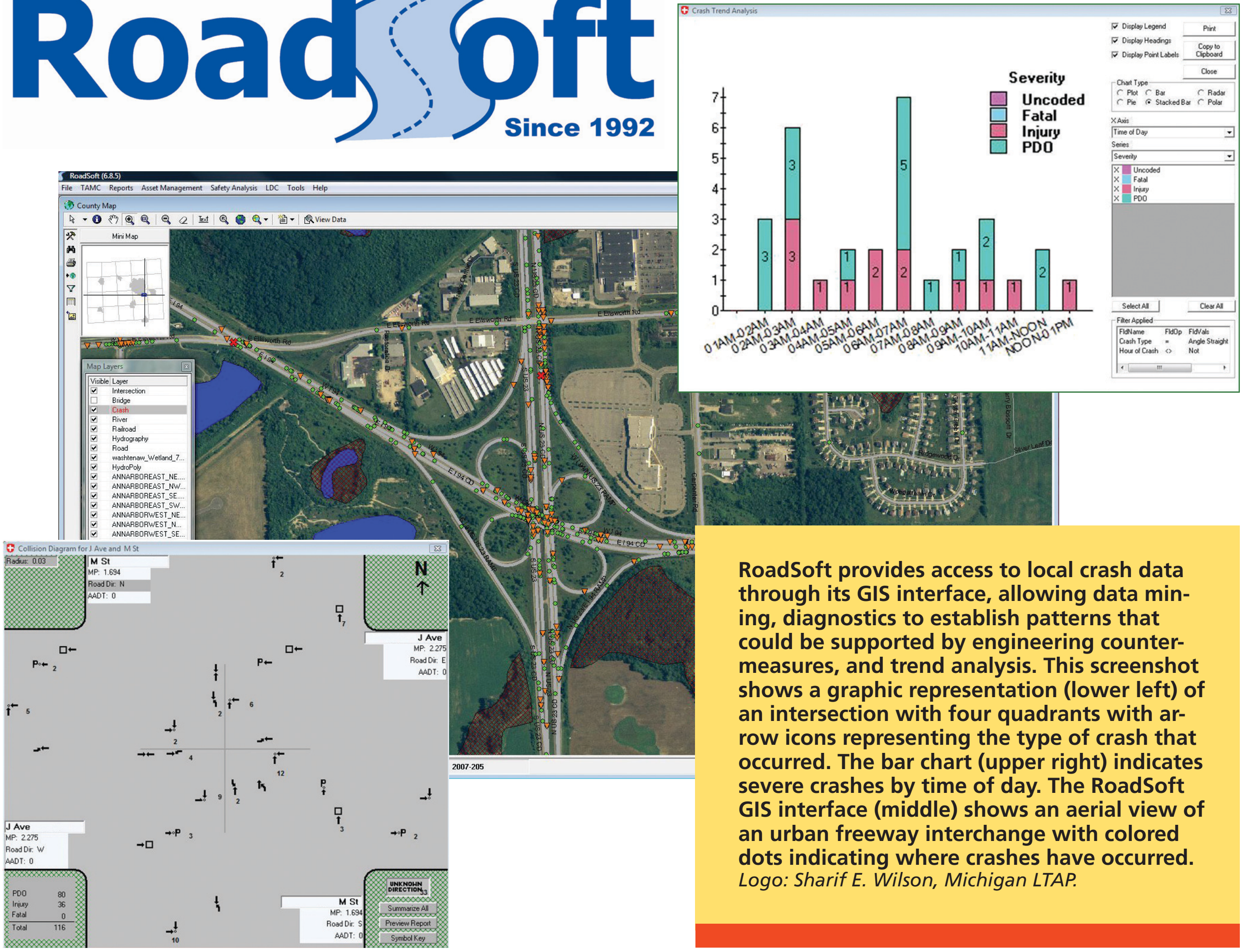
The morning session covered an overview of crash data and demonstrated various methods of screening crash data for high-crash locations and conducting site-level collision analysis. "Before a computer was even switched on, the discussion focused on the benefits and drawbacks of the various analysis methods, and where each is most appropriately used," says Nordberg.

The afternoon session dealt with the geometric, operational, and human factors that cause crashes; how to select and evaluate effective countermeasures; and before-and-after studies that can verify that a solution is working. Ken Johnson, program and development engineer, Genesee County Road Commission, says, "The RoadSoft safety module provides an array of powerful analytical tools to help identify locations that can benefit most from appropriate countermeasures. Previously, agencies didn't have the tools necessary to conduct this level of analysis."

The tools, combined with the training, make traffic safety analysis available to agencies regardless of their size. "The accessibility of the data and the user-friendliness of the RoadSoft tools make this something that even the smallest transportation agency can grow into as its traffic safety analysis needs dictate," says Michael Latuszek, senior transportation planner, St. Clair County Transportation Study. "Agencies need to take advantage of the training and technical support provided by LTAP. They can't afford not to."

Education Helps Achieve Traffic Safety Goals

In the context of the 4-E's of traffic safety—engineering, enforcement, emergency services, and education—the responsibility for engineering falls quite squarely on transportation professionals. Police officers cover enforcement. First responders and medical staff handle emergency services. Colleges and universities educate the technical workforce,



RoadSoft provides access to local crash data through its GIS interface, allowing data mining, diagnostics to establish patterns that could be supported by engineering countermeasures, and trend analysis. This screenshot shows a graphic representation (lower left) of an intersection with four quadrants with arrow icons representing the type of crash that occurred. The bar chart (upper right) indicates severe crashes by time of day. The RoadSoft GIS interface (middle) shows an aerial view of an urban freeway interchange with colored dots indicating where crashes have occurred. *Logo: Sharif E. Wilson, Michigan LTAP.*

particularly those just beginning their careers, with ongoing professional development training offered through FHWA's National Highway Institute and Resource Center, LTAP and TTAP centers, and industry associations.

If traffic safety goals are to be met nationwide, engineers and other professionals, including planners, public works managers, law enforcement officials, driver trainers, and others must take joint responsibility for educating the nontechnical community. And traffic safety professionals need to assume responsibility for educating their practicing peers. With some creativity, and by tapping into existing resources at FHWA and at the LTAP and TTAP centers, engineers can become effective agents of change, creating a culture of traffic safety and saving lives in the process.

Terance L. McNinch is director of Michigan's LTAP and the Technology Development Group (TDG), both housed within the Michigan Tech Transportation Institute (MTTI) at Michigan Technological University (MTU) in Houghton, MI. McNinch has worked with LTAP since 1992. He holds a B.S. in scientific and technical communication and an M.S. in rhetoric and technical communication, both from MTU. His research interests include asset management implementation at the local level and creative techniques for communicating technical information to technical and nontechnical audiences.

Timothy K. Colling is assistant director of Michigan's LTAP and TDG and a senior research engineer with MTTI at MTU. He holds a B.S. in environmental engineering and an M.S. in civil engineering from MTU. He is currently completing his Ph.D. in civil engineering at MTU with a focus on traffic safety. Colling's research interests include asset management systems and traffic safety engineering.

For more information, contact Terry McNinch at 906-487-2102 or tlmcninc@mtu.edu. For a copy of the Common Sense Solutions for Intersection Safety Problems *training material, see www.michiganltap.org/CSS. For more information on RoadSoft, see www.roadsoft.org. For information on MDOT's Local Safety Initiative, contact Dale Lighthizer at 517-373-2334 or lighthizerd@michigan.gov. To listen to the "We Need a Stop Sign" phone call used in the Traffic Safety for Elected Officials training, see www.michiganltap.org/stopsigncall.*

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.

Management and Administration

USDOT Releases Guidelines for Pandemic Flu Planning

USDOT recently released guidelines to help its modal subsectors and other public and private sector businesses plan for a severe influenza pandemic. The sector-specific guidelines are annexes to the *Pandemic Influenza Preparedness, Response, and Recovery Guide for Critical Infrastructure and Key Resources* developed by the U.S. Department of Homeland Security.

The highway and motor carrier subsector annex serves as a reference for owner-operators and a practical tool for business planners to augment and tailor existing emergency response plans to the potential challenges posed by an influenza pandemic.

The document addresses the major challenges the highway and motor carrier subsector could face in seven key areas of vulnerability: services, functions, and processes; assets and equipment; raw materials and supplies; workers; interdependencies; regulatory issues; and impacts from community disease mitigation strategies.

USDOT cautions departments of transportation (DOTs) and freight operators that failure to prepare for such an event could leave them without the staff, equipment, or supplies necessary to continue providing essential transportation services for their customers and the Nation.

To download the highway and motor carrier annex, visit www.dot.gov/pandemicflu/pdf/highwaymotorcarrier.pdf. For the complete guidelines, visit www.pandemicflu.gov/plan/pdf/cikrpandemicinfluenzaguide.pdf.

RITA Renames Vehicle Infrastructure Integration Initiative

In January 2009, USDOT's Research and Innovative Technology Administration (RITA) introduced a new name and logo for one of the department's key intelligent transportation systems (ITS) initiatives. The program, formerly known as Vehicle Infrastructure Integration (VII), now will be called IntelliDrive℠. The program covers a group of ITS initiatives that offer motorists greater situational awareness of potential threats and imminent hazards within their vehicles' environment.

In recent years, the VII program has been a major initiative of the department's ITS Joint Program Office, including a series of demonstration projects known as SafeTrip-21. (See "Gearing Up for SafeTrip-21" in the September/October 2008 issue of PUBLIC ROADS.)

IntelliDrive conveys the full potential of these technologies to enhance the safety, mobility, and convenience of everyday transportation. Though its name changed, the program continues to focus on developing a networked environment supporting high-speed wireless transactions among vehicles and between vehicles and infrastructure components or hand-held devices to facilitate safety and mobility applications.

For more information, visit www.its.dot.gov/intellidrive/index.htm or www.vehicle-infrastructure.org.

Technical News

FHWA Offers New Tools for Reviewing Work Zone Processes

In November 2008, the Federal Highway Administration (FHWA) created the Work Zone Process Review Toolbox, an online collection of tools to help DOTs and FHWA division office personnel conduct reviews of work zone processes. Periodic evaluations of work zone policies and procedures help an agency identify and manage the safety and mobility impacts of work zones. Under the Work Zone Safety and Mobility Rule, FHWA requires these reviews every 2 years to assess the effectiveness of current processes and make recommendations for improvement.

Housed on FHWA's "Work Zone Mobility and Safety Program" Web site, the toolbox features an indepth explanation of work zone reviews. For example, the site describes how reviews help answer questions about how work zones are performing with respect to mobility and safety and whether customer expectations are being met. The site provides information to help determine the goals and scope of the reviews, expected outcomes, staff members who should be involved, and possible data sources. Other links include frequently asked questions and a resources section that provides information on training and sample practices and documents.

To access the toolbox, visit www.ops.fhwa.dot.gov/wz/prtoolbox/pr_toolbox.htm.

FHWA Develops Resources to Prevent And Mitigate ASR in Concrete

FHWA's Alkali-Silica Reactivity (ASR) Development and Deployment Program has developed several resources related to preventing and mitigating ASR in portland cement concrete pavements and structures. ASR occurs when silica in some aggregates and alkalis in concrete combine with water to form a gel-like substance. As the gel absorbs water and expands, it causes the concrete to crack, leading to premature deterioration and loss in serviceability.

FHWA's ASR program offers field application and demonstration projects, research initiatives, newsletters, publications, and an online reference center. A primary focus of the program is implementing field demonstration projects. FHWA provides technical assistance to States participating in the demonstrations, including installing instrumentation for data collection and evaluating and analyzing the data.

The program offers publications, including a free quarterly newsletter titled *Reactive Solutions*, which provides information on ASR and updates on the program. Other publications include two reports on ASR: *Report on Determining the Reactivity of Concrete Aggregates and Selecting the Appropriate Measures for Preventing Deleterious Expansion in New Concrete Construction* (FHWA-HIF-09-001). A second report is under review with anticipated release in 2009.

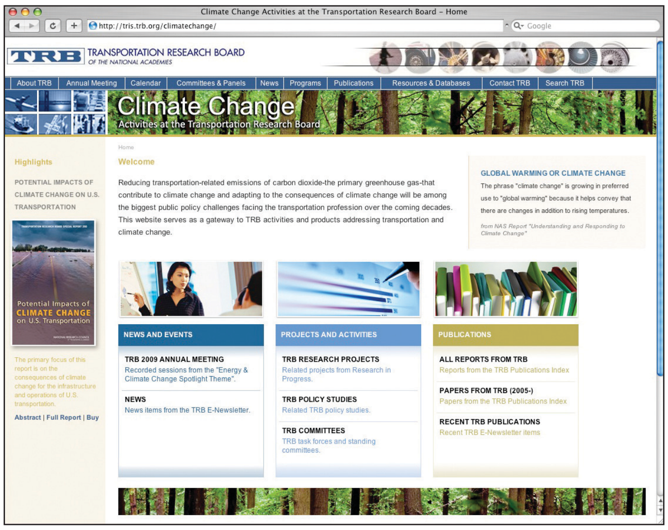
FHWA also is developing an online reference center to house the research reports; guidance documents; information on State ASR specifications; and details on past, current, and planned field trials. FHWA expects to launch the reference center in 2009.

For more information on the reference center or to download issues of the Reactive Solutions *newsletter or publication FHWA-HIF-09-001 at no cost, visit www.fhwa.dot.gov/pavement/concrete/asr.cfm.*

Public Information and Information Exchange

TRB Launches Climate Change Web site

The Transportation Research Board (TRB) recently created a Web site designed to serve as a gateway to information on the organization's activities and products related to transportation and climate change. The Web site responds to the push to reduce transportation-related emissions of carbon dioxide—a greenhouse gas that contributes to climate change—and adapt industry practices to mitigate the consequences of a changing climate.



Shown here is the TRB "Climate Change" Web site.
Source: TRB.

The Web site contains information on TRB news and events, projects and activities, and publications. The "Projects and Activities" section highlights research projects, policy studies, and information on TRB committees. The "Publications" section lists all TRB reports and papers on topics related to climate change. The site also links to transportation and climate change information produced by other organizations that have been highlighted in past issues of the *TRB E-Newsletter*.

Visit the Web site at http://tris.trb.org/climatechange.

TRB

FHWA Report Looks at Impact of Planned Special Events

FHWA recently released a study on the influence that large planned special events (PSEs) have on the economy and congestion at the national level. The purpose of the study was to gain a clearer understanding of the scale of PSEs and their economic impacts and to highlight the important role that transportation planning should play in managing the traffic logistics of these events.

Transportation planners define PSEs as public activities with a scheduled time and location that affect normal operations of the transportation system as a result of increased travel demand and/or reduced capacity attributed to event staging. According to the report, approximately 24,000 PSEs with more than 10,000 in attendance occur annually or approximately 470 per week at the national level. This translates to about 80 event days per million persons per year.

FHWA's findings suggest that a large number of these events recur at permanent venues, and the vast majority of these permanent venues are located near interstate highways and are well served by transit. As a result, a significant opportunity exists to employ various mitigation techniques, such as timing events to avoid peak travel times, to minimize travel interruptions associated with these events.

To view the report, visit http://ops.fhwa.dot.gov/publications/fhwahop08022/index.htm.

Caltrans Tests Magnet-Guided Buses

The California Department of Transportation (Caltrans) is testing technology that guides buses by magnets, just as trolleys are guided by rails. The pilot program includes conducting the first-ever test of this magnetic system in revenue service on public bus lines.

California PATH, University of California Berkeley

This Caltrans magnet-guided bus is precision docking at a bus stop during a demonstration run on State Route 185 in San Leandro, CA.

The technology, known as Vehicle Assist and Automation, keeps a bus centered in its lane via magnets embedded in the roadway and enables the bus to travel safely in narrow spaces at a higher rate of speed. Buses can pick up more passengers and complete their routes in less time. Caltrans officials believe the technology would make travel times more comparable to that of personal vehicles, therefore persuading more people to switch from their cars to buses, reducing congestion.

Caltrans will conduct tests on Alameda-Contra Costa Transit's Transbay Express on a 4-mile (6.4-kilometer) stretch of State Route 92 from Hesperian Boulevard to the San Mateo-Hayward Bridge toll plaza. The other test will be performed with the Lane Transit District in Eugene, OR, on its EmX Bus Rapid Transit system.

Caltrans

Signs Identify Bridges To Be Repaired, Replaced in Missouri

The Missouri Department of Transportation (MoDOT) installed signs bearing the department's Safe & Sound logo on more than 800 bridges to indicate which ones will be improved over the next 5 years. The signs are part of MoDOT's Safe & Sound Bridge Improvement Program, which will begin construction on at least 100 bridges in early 2009. The signs indicate that the bridges need attention and will be repaired or replaced by October 2014.

According to MoDOT officials, the purpose of the signs is to alert drivers that these bridges will likely be closed during construction and to plan accordingly. There is at least one bridge that needs repair or replacement in every Missouri county. Information on construction schedules, alternate routes, and closures is available at www.modot.org. A list of the bridges in the program and maps of their locations are posted on the project Web site at www.modot.mo.gov/safeandsound.

MoDOT

MoDOT

More than 800 bridges in Missouri have been identified with Safe & Sound signs, such as the one shown here, indicating they will be repaired or replaced within 5 years.

NPHQ Awards Highlight Highway Achievements

In November 2008, the National Partnership for Highway Quality (NPHQ) recognized highway projects and organizational teams that successfully improved quality or customer service related to highway planning, project delivery, maintenance, safety, congestion management, workforce training, environmental stewardship, or operations. A group of transportation experts selected the winners under the auspices of NPHQ, which is a coalition of highway stakeholders from Federal and State government, private industry, and academia.

Awards were given in four categories, each recognizing a particular strength. The following organizations received awards for partnering: Michigan Department of Transportation, Pennsylvania Department of Transportation (PennDOT), Kansas Department of Transportation, and New Mexico Department of Transportation (NMDOT).

In the category "Breaking the Mold," the following DOTs earned awards: Utah Department of Transportation (UDOT), Virginia Department of Transportation, and Maryland State Highway Administration.

For public communications, NPHQ honored Washington State Department of Transportation, PennDOT, and NMDOT. Two DOTs received awards for risk taking: PennDOT and NMDOT. Other winners included UDOT for workforce training and the Calhoun County (AL) Highway Department for its innovative vegetation management program.

For more project information, visit www.nphq.org.

NPHQ

Policy and Legislation

USDOT Signs Agreement to Relieve Congestion on I–95

In December 2008, USDOT and the I–95 Corridor Coalition signed an agreement to deploy cutting-edge technology to relieve congestion and improve safety on I–95. The agreement commits the coalition to evaluate innovative approaches for project delivery and to educate States on the use of alternative financing and operation mechanisms.

The agreement calls for doubling the fuel efficiency of the region's vehicle fleet and diversifying fuel use. Further, it supports a seamless, integrated, multimodal passenger and freight network to link the major metropolitan regions.

The coalition estimates that by 2040 travel along I–95 will increase by 70 percent. Congestion will jump by 84 percent, fuel consumption will increase 34 percent, and the amount of trucking will double. The agreement aims to curb these projections by working across State boundaries to improve mobility along this critical travel corridor.

For more information on the I-95 Corridor Coalition, visit www.i95coalition.org.

Laws Expected to Improve Work Zone Safety in Michigan

In October 2008, Michigan Governor Jennifer M. Granholm signed two new laws that impose stiffer penalties for motorists who kill or injure someone in a Michigan road construction work zone. The legislation (Public Acts 296 and 297 of 2008) will levy fines up to $7,500 and 15 years in jail.

State transportation officials hope the potential for such stiff penalties will help motorists focus more closely on their responsibility to drive safely through construction zones, creating a safer environment for everyone. According to the Michigan Department of Transportation (MDOT), the vast majority (95 percent) of the fatalities that occurred in work zones in 2007 involved motorists and their passengers.

House Bill 4468 (2008 PA 296) extends the penalties to motorists who hit anyone—not just workers—in a work zone, and House Bill 4469 (2008 PA 297) provides sentencing guidelines for motorists who cause injury or death to another person in a work zone.

MDOT

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, Martha Soneira, via e-mail (martha.soneira@fhwa.dot.gov), telephone (202–493–3468), or mail (Martha Soneira, 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.

Training Update

NATIONAL HIGHWAY INSTITUTE

by Norah Davis

Accelerating Deployment Of New Technologies

Suppose that you've developed an innovative technology or other new solution to a transportation problem. Unless you can persuade the transportation community to adopt the innovation, it will have no real benefit either to your organization or to society. Deploying new technologies can take years because of the difficulty of persuading people to try something new. Case in point: the deployment of Superpave™ took 12 years and cost $100 million.

Officials in government organizations tend to be cautious and want examples of successful implementation before they make a change. As a result, reports on new research often sit on the shelf, or someone champions the new technology but lacks support from the organization's leadership or funding for deployment. So how can a new technology or approach overcome these obstacles and get off the shelf and onto the highway?

Enter a new National Highway Institute (NHI) course, Leap Not Creep: Accelerating Innovation Implementation (FHWA-NHI-134073). This 2.5-day, Web-conference/instructor-led training is designed to provide transportation professionals with the tools to mainstream innovations into an agency's standard practice. Participants learn about the importance of marketing the innovation and how to do it successfully, how to locate funding, and strategies for neutralizing roadblocks to implementation. The course's target audience includes project managers, engineers, analysts, senior managers, and communications specialists.

Leading by Example

"Getting people to incorporate an evolutionary, transformative practice in their day-to-day business is difficult," says Lawrence H. Orcutt, chief of the Research and Innovation Division at the California Department of Transportation (Caltrans), which hosted the course's pilot session. "The key is change. And you can't get people to change without a solid business case and a marketing plan to convince them that this innovation will help them do their jobs."

An example described during the pilot was a new system that Caltrans developed for protecting construction and maintenance workers when they are working on roadside shoulders. Named after an employee who lost a leg on a road in the bay area, the Balsi Beam is a tractor-trailer device that provides a 30-foot (9.1-meter)-long work zone—a shield of steel instead of cones.

As a Caltrans maintenance manager said, "We should have something better than cones to protect our people." Commercializing the device through a private contract took Caltrans more than 3 years because of the challenges related to selling licenses on an evolutionary technology for a fair market value. Orcutt adds, "You need to have innovation champions at the working, mid, and executive levels to successfully deploy research that achieves its full benefits."

Road safety audits like this one simulated in McLean, VA, are one of the success stories highlighted in the NHI course Accelerating Innovation Implementation.

NHI Innovations Web Conference: Sample Topics

- Road safety audits
- Performance contracting
- Applications of self-consolidating concrete
- Modern roundabouts
- Inservice bridge inspection techniques
- Applications of prefabricated bridge elements
- Improving pavement edge performance
- Pavement smoothness

Creative Solutions

Kathleen A. Bergeron, a marketing specialist with the Federal Highway Administration's Highways for LIFE program, describes another example presented during the course: "A Texas Department of Transportation [TxDOT] roadside litter campaign used an innovative approach. A company hired by TxDOT conducted market research to determine the target audience. The typical litterer in Texas turned out to be an 18- to 34-year-old male who drives a pickup truck. Approaches that appeal to children [such as the U.S. Forest Service's Woodsy Owl] or environmentalists [the crying Indian campaign developed by the Ad Council for the Keep America Beautiful program] did not work in Texas." Based on the market research, the campaign instead adopted the macho-sounding slogan "Don't mess with Texas" and ran television advertisements featuring two Dallas Cowboys football players offering to punch out litterers. The campaign was hugely successful, reducing roadside litter by 59 percent within 3 years.

The key to success is marketing research. Caltrans' Orcutt sums it up, "Do you want your idea to be used? If so, you need to acquire the tools this class offers."

To read the full course description, visit the NHI Web site at www.nhi.fhwa.dot.gov.

Norah Davis is editor of PUBLIC ROADS.

Internet Watch

by Scott Mitchell

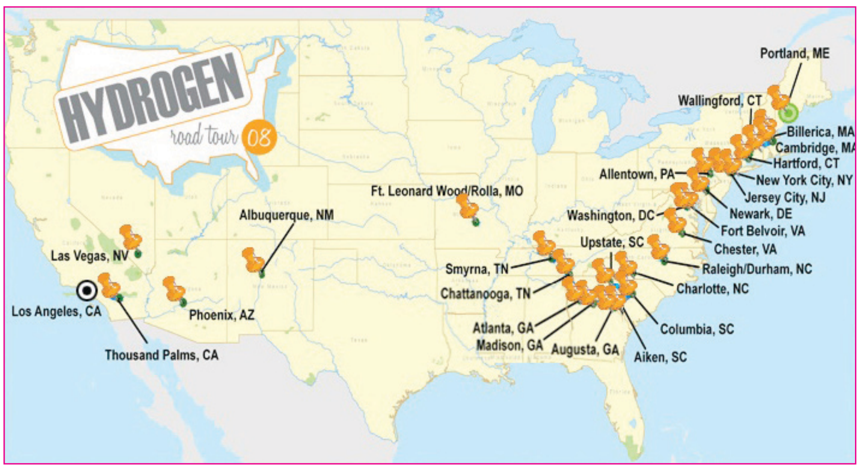
The Hydrogen Fuel Initiative And Road Tour 2008

One of the greatest challenges facing the United States in the coming decades is achieving energy independence. Record high oil prices rocked the U.S. economy in 2008. To reduce the Nation's reliance on oil imports and minimize economic vulnerability to disruptions in the supply, researchers are focusing on producing alternative fuels domestically. For several years, the Federal Government has been working to help develop new hydrogen technologies as part of a balanced energy plan to reduce dependence on foreign oil and limit greenhouse gas emissions. Hydrogen and fuel cells are two technologies that address these national energy challenges, and the U.S. Department of Transportation (USDOT) is calling attention to them through a vehicle tour and a new Web site.

Road Tour 2008

In summer 2008, USDOT and its partners made history by driving hydrogen-powered vehicles across the United States. From August 11–23, the Hydrogen Road Tour made 31 stops in 18 States from Maine to California. The Federal Government, State governments, and private industry entities organized the tour to demonstrate hydrogen fuel cell and combustion engine vehicles in real-world driving conditions. The tour also aimed to introduce the public to the capability, range, durability, reliability, and cost that U.S. consumers might expect from hydrogen-powered vehicles.

At most stops, members of the media, invited guests, and the public had an opportunity to see these cutting-edge vehicles up close and to discuss the technologies with experts on hand. In addition, the public was given an unprecedented opportunity to get behind the wheel and drive a hydrogen-powered vehicle. Existing and mobile refueling stations offered opportunities for the motorists to see how to refuel these vehicles with hydrogen.



USDOT

This map highlights the stops along the 2008 Hydrogen Road Tour, starting in Portland, ME, and ending in Los Angeles, CA.

The tour attracted more than 6,500 attendees and 1,654 citizen test-drivers. In addition, more than 8.6 million viewers learned about the tour and hydrogen-powered vehicles on local television.

For USDOT, this effort represents a key step toward making alternative fuel sources a reality. "The technology necessary to put these cars on the road and keep them moving exists today," says Administrator Paul Brubaker of the USDOT Research and Innovative Technology Administration (RITA). "The question is not if hydrogen powered vehicles will be available commercially, but when."

One main goal of the Hydrogen Fuel Initiative is to help create a national market demand for alternatively powered vehicles. Along with its partners, USDOT is working to ensure that hydrogen transportation technologies are safe, to define design standards for future hydrogen vehicles and infrastructure, to accelerate technology transfer, and to increase public understanding of hydrogen-powered transportation.

For a map of the cities visited, as well as tour details and highlights, visit http://hydrogenroadtour08.dot.gov.

Stay Informed Through the Hydrogen Portal

As the Nation moves toward energy independence, USDOT recognizes that developing alternative fuel solutions is a long-term effort. According to the National Research Council's (NRC) *Transitions to Alternative Transportation Technologies—A Focus on Hydrogen*, significant deployment of hydrogen vehicles most likely will not happen before 2015. NRC asserts that a $200 billion investment is needed between 2008 and 2023 to make hydrogen fuel cell vehicles cost competitive with conventional vehicles. Costly new fuel stations and other distribution infrastructure, such as hydrogen pipelines, will be needed to make deployment a reality.

In the meantime, USDOT's Hydrogen Portal at http://hydrogen.dot.gov provides an online home for the latest information about these technologies. The Web site includes a roadmap document that outlines the roles and activities of each modal agency within the Department, highlights current and planned USDOT activities supporting the national hydrogen initiative, and discusses anticipated paths and timeframes for deploying hydrogen infrastructure. The portal also contains information about safety, codes, and standards; hydrogen-related projects across USDOT; and upcoming events.

As the Nation enters a new era defined by energy independence, USDOT will continue exploring and fostering technologies that promise improved energy efficiency and environmental protection.

Scott Mitchell is an information technology specialist in the RITA Office of the Chief Information Officer.

Communication Product Updates

Compiled by Zachary Ellis 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.

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
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703–605–6000
Toll-free number: 800–553–NTIS (6847)
Web site: www.ntis.gov

Address requests for items available from the R&T Product Distribution Center to:

R&T Product Distribution Center
Szanca Solutions/FHWA PDC
13710 Dunnings Highway
Claysburg, PA 16625
Telephone: 814–239–1160
Fax: 814–239–2156
E-mail: 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 Turner-Fairbank Highway Research Center's Web site at www.tfhrc.gov, the National Transportation Library's Web site at http://ntl.bts.gov, or the OneDOT information network at http://dotlibrary.dot.gov.

Seeing in the Dark: Improving Understanding Of Driver Visibility Requirements at Night
Publication No. FHWA-HRT-09-024

Advancing knowledge and understanding of how motorists acquire and act on visual information while driving at night is the goal of a new project launched by FHWA in 2008. This program factsheet explains the Increased Understanding of Driver Visibility Requirements, a project under FHWA's Exploratory Advanced Research Program, which will develop a theoretical framework for determining the quantity and quality of visual information drivers need to navigate two-lane, rural roads safely.

Conducted by the National Institute of Standards and Technology, Texas Transportation Institute (TTI), and Science Applications International Corporation, the project will investigate how human drivers and autonomous robotic vehicles negotiate curves at night, with the goal of developing a software program that can predict how both will respond to different combinations of visual guidance. This guidance can range from centerlines and edgelines to delineators and raised pavement markers.

In summer 2008, TTI measured driver performance under varying levels of pavement marking luminance. Data from this initial study will help to refine cognitive task analysis of the autonomous vehicle, which will drive the test course at TTI in April 2009 under the same conditions as those experienced by the human participants. A final report on the project is due in late 2009.

Limited printed copies of this factsheet are available from FHWA's Office of Corporate Research, Technology, and Innovation Management.

Test Track and Driving Simulator Evaluations Of Warnings to Prevent Right-Angle Crashes at Signalized Intersections
Publication No. FHWA-HRT-08-070

FHWA conducted two experiments, one simulated and one on a test track, to validate the concept of a system designed to warn potential victims of a likely red-light violator. The warning system uses sensors to detect vehicles that are unlikely to stop at red traffic signals and uses signs and flashing lights to warn drivers who might collide with a violator.

Several human factor issues need to be addressed before such a system could be deployed. The experiments for this study addressed one of these issues—whether, if warned, a sufficient number of drivers would respond in a way that would enable them to avoid a right-angle collision. The results suggest that in a case where no other vehicles precede or follow, a majority of drivers who receive a conspicuous warning will act by braking sharply. Drivers responded similarly in both tests. The test track results support the continued use of driving simulators in system development. Researchers will conduct further examinations to assess responses to warnings given to drivers within a stream of traffic.

This report is available at www.tfhrc.gov/safety /pubs/08070/index.htm and from NTIS under order number PB2009102752. Printed copies also are available from FHWA's R&T Product Distribution Center.

Office of Infrastructure R&D Factsheet
Publication No. FHWA-HRT-08-069

This factsheet provides an overview of FHWA's Office of Infrastructure Research and Development (R&D), which conducts and administers infrastructure R&D programs and projects that address problems of national concern on the U.S. highway system. The Office focuses on R&D where there is an appropriate Federal role by virtue of national needs, scope, duration, or risk. This role is reflected in various overarching strategies involving long-term infrastructure performance, durable infrastructure systems, accelerated highway construction, environmentally sensitive highway infrastructure, performance-based specifications, and comprehensive and integrated infrastructure asset management.

The outcomes delivered through pursuit of these strategies will benefit the American public by enabling improvements in the safety, performance, and cost-effectiveness of the Nation's highway infrastructure, while minimizing the environmental impacts of highway construction, maintenance, and rehabilitation. The goals are to reduce highway congestion, improve safety, and enhance the overall driving experience for motorists.

Printed copies are available from FHWA's R&T Product Distribution Center.

Long-Term Pavement Performance Compliance With Department of Transportation Information Dissemination Quality Guidelines
Publication No. FHWA-HRT-08-065

This document provides information on the compliance of the Long-Term Pavement Performance (LTPP) program with the guidelines issued in the U.S. Department of Transportation (USDOT) Information Dissemination Quality Guidelines. USDOT developed these guidelines in response to requirements of Section 515 of the Treasury and General Government Appropriations Act for fiscal year 2001.

The purpose of the guidelines is to maximize the quality, utility, objectivity, and integrity of information disseminated by the Federal Government. The document discusses the activities performed under the LTPP program and addresses the policies and procedures established by the guidelines.

This report is available from NTIS under order number PB2009103923. Printed copies also are available from FHWA's R&T Product Distribution Center.

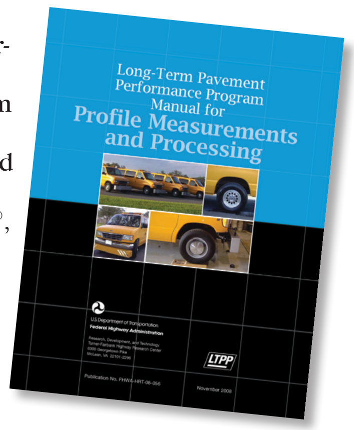
LTPP Computed Parameter: Frost Penetration
Publication No. FHWA-HRT-08-057

As the pavement design process moves toward mechanistic-empirical techniques, knowledge of seasonal changes in pavement structural characteristics becomes critical. This report describes a methodology for determining frost penetration in unbound pavement layers and subgrade soil using temperature, electrical resistivity, and moisture data collected for instrumented LTPP seasonal monitoring program (SMP) sites.

The report also contains a summary of LTPP estimates of frost depth and a detailed description of the LTPP computed parameter tables containing information on frost penetration for 41 LTPP SMP sites. The analysis methodology and the accompanying E-FROST program use in situ soil temperature as a primary source of data to predict frost depth in unbound pavement layers. Researchers also used electrical resistivity and moisture data as supplemental data sources for the analysis when temperatures were close to the freezing isotherm. The Enhanced Integrated Climatic Model served to fill intermediate gaps in the measured soil temperature data.

Printed copies are available from FHWA's R&T Product Distribution Center.

Long-Term Pavement Performance Program Manual for Profile Measurements and Processing
Publication No. FHWA-HRT-08-056



This manual includes operational procedures for measuring longitudinal pavement profiles for the LTPP program using the International Cybernetics Corporation road profiler, Face Construction Technologies, Inc.'s Dipstick®, and the rod and level. The manual contains procedures for measuring transverse profiles of the pavement using Dipstick.

The document also describes procedures for equipment calibration, data collection, recordkeeping, equipment maintenance for each of the profiling devices, processing procedures for profile data collected in the field, and guidelines for performing inter-regional comparison tests among the LTPP profilers.

Printed copies are available from FHWA's R&T Product Distribution Center.

Notice: The mailing address information for the R&T Product Distribution Center in the "Communication Product Updates" section of PUBLIC ROADS has been removed from all online Web issues.

Conferences/Special Events Calendar

Date	Conference	Sponsors	Location	Contact
September 13–16, 2009	APWA Congress and Expo	American Public Works Association (APWA)	Columbus, OH	Dana Priddy 816-595-5241 dpriddy@apwa.net www.apwa.net/congress
September 14–15, 2009	Integrated Corridor System Management Modeling Best Practices Workshop	California Department of Transportation (Caltrans), Transportation Research Board (TRB)	Irvine, CA	Matthew Miller 202-334-2608 mamiller@nas.edu www.TRB.org /conferences/2009/Corridor
September 16–17, 2009	North American Freight Flows Conference 2009	TRB	Irvine, CA	Matthew Miller 202-334-2608 mamiller@nas.edu www.TRB.org /conferences/2009/NAFF
September 21–25, 2009	16th World Congress on ITS	ITS America	Stockholm, Sweden	Nicole Oliphant ITS America 202-721-4215 NOliphant@itsa.org www.itsworldcongress.com
September 22–24, 2009	National Highway Data Workshop and Conference	Caltrans and the University of California, Berkeley's Institute of Transportation Studies, Technology Transfer Program	Oakland, CA	Brian Domsic 916-653-3272 brian.domsic@dot.ca.gov www.techtransfer.berkeley.edu /hidac
October 19–22, 2009	8th National Conference on Asset Management	TRB	Portland, OR	Matthew Miller 202-334-2608 mamiller@nas.edu www.TRB.org /conferences/2009/Asset
October 22–27, 2009	AASHTO Annual Meeting	American Association of State Highway and Transportation Officials (AASHTO)	Palm Desert, CA	Hannah Whitney 202-624-5800 hwhitney@aashto.org www.transportation.org /meetings/181.aspx
October 25–29, 2009	4th International Conference on Women's Issues in Transportation	Women's Issues in Transportation Committee, TRB; Federal Highway Administration; Swedish Governmental Agency for Innovation Systems; United Kingdom Department for Transport; University of California, Berkeley; University of California, Davis; University of Southern California	Irvine, CA	Martine Micozzi 202-334-3177 mmicozzi@nas.edu

Accelerating Deployment of Innovative Technologies

New NHI course helps you mainstream your transformative practice.

Getting new technologies off the shelf and onto the highway can take years. Persuading agencies to change requires a solid business case and marketing plan to convince people that your innovation will help them do their jobs better, faster, and more cost effectively.

Recognizing this need, the Federal Highway Administration's Highways for LIFE program worked with technology deployment professionals from State and Federal transportation agencies, local transportation assistance programs, and major transportation research groups to create an appropriate course.

The National Highway Institute's (NHI) new course, **Leap Not Creep: Accelerating Innovation Implementation (FHWA-NHI-134073)**, helps participants learn about:

- Avenues for identifying innovative technologies
- Importance of marketing an innovation
- Components of a marketing plan
- Funding resources
- Strategies for neutralizing implementation obstacles

The training covers putting an innovation into practice, outlines the key features of successful implementations, and describes how to develop an implementation plan. Case studies highlight successful innovations such as road safety audits, prefabricated bridge elements, new protection for construction workers, a market-based roadside litter campaign, and improved pavement edge performance.

The course will benefit team leaders, project managers, engineers, transportation analysts, and communications specialists.

Available for scheduling by summer 2009.

For course information, visit
www.nhi.fhwa.dot.gov

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Federal Highway Administration

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