Public Roads

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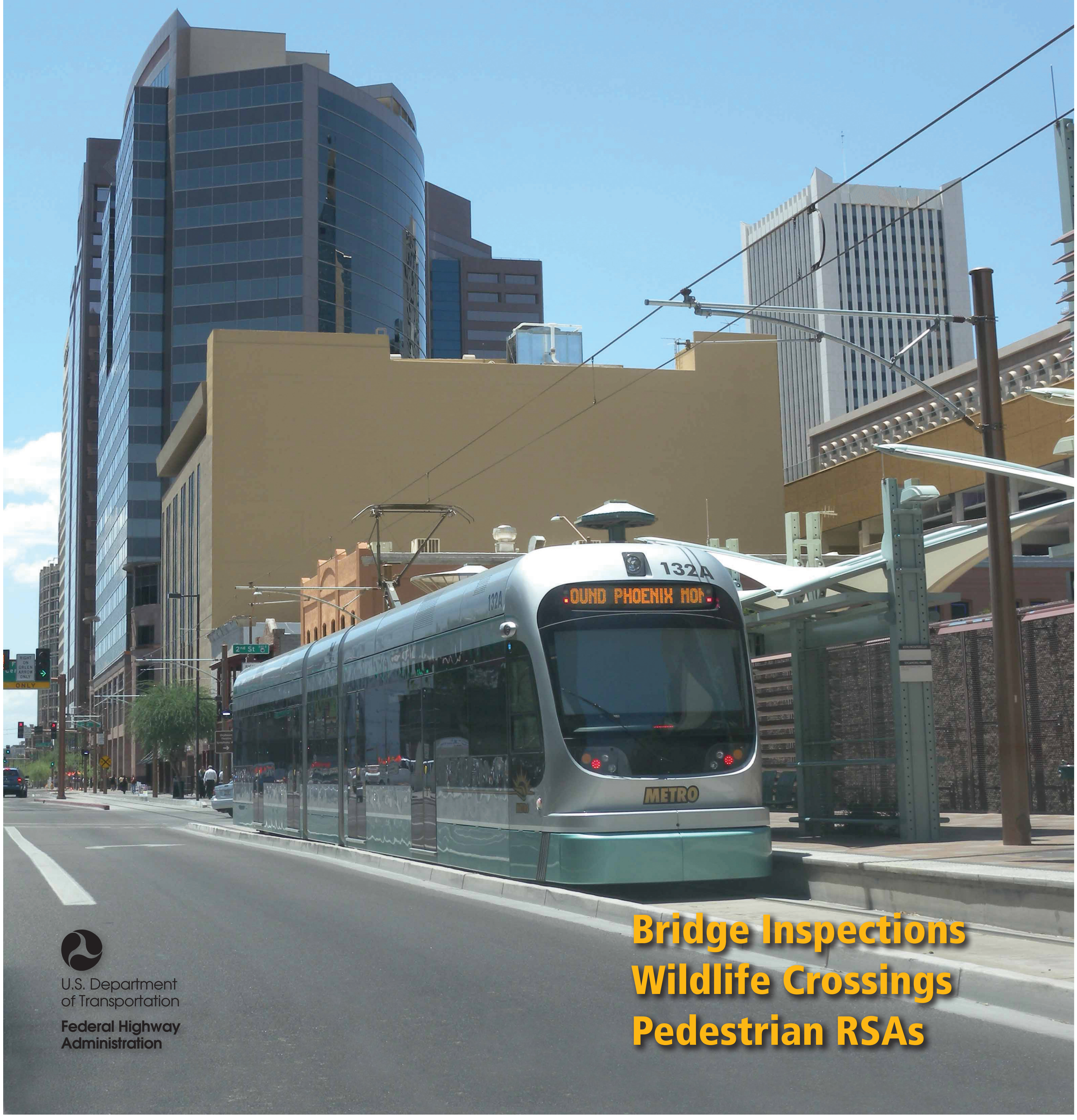


Bridge Inspections
Wildlife Crossings
Pedestrian RSAs

U.S. Department of Transportation
Federal Highway Administration

Public Roads

September/October 2009 www.tfhrc.gov Vol. 73, No. 2

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

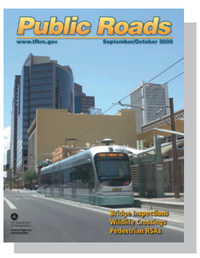
Articles

Page 10

Page 14

Page 22

Departments



Front cover—This newly constructed light rail system (shown here in downtown Phoenix) began operating in late 2008. The 20 miles (32 kilometers) of track are at grade, and the trains run parallel to road traffic with a coordinated signal system. Ensuring the safety of pedestrians and other road users is a critical focus of the system's designers and operators. For the latest on efforts to improve pedestrian safety, see "Road Safety Audits for Pedestrian Facilities" on page 22 of this issue of PUBLIC ROADS. *Photo by Kohinoor Kar, ADOT.*

Back cover—Electric mats, such as this one installed on a two-lane road near Price, UT, are a new technology deployed to help prevent collisions between vehicles and large animals like deer, elk, and moose. When the mats are installed on highways or interstate ramps, they discourage animals from entering fenced sections of roadway and becoming trapped between wildlife fences. For more information, see "Advances in Wildlife Crossing Technologies" on page 14 of this issue of PUBLIC ROADS. *Photo by S. Lampman, ElectroBraid Fence.*

U.S. Department of Transportation
Federal Highway Administration

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Guest Editorial

Rising to the Safety Challenge

On July 2, 2009, the U.S. Department of Transportation (USDOT) announced that the number of traffic fatalities reported in 2008 hit their lowest level since 1961, a trend that appears likely to continue into 2009. This issue of PUBLIC ROADS presents some of the programs that are helping make that happen. These programs take advantage of cutting-edge technologies and use the expertise of multidisciplinary teams, including both safety and design experts, to drive the fatality numbers down.

Although the Nation is making real progress, the fact remains that 37,261 people lost their lives on U.S. roads last year. As Transportation Secretary Ray LaHood noted during the July 2 announcement, "while the number of highway deaths in America has decreased, we still have a long way to go."

For example, during the period when most crash numbers were dropping, the number of motorcycle fatalities grew 2.2 percent. With 5,290 fatalities in 2008, motorcycle deaths now account for 14 percent of all highway fatalities. In addition, the fatal and serious crashes on rural roads still constitute the majority of deaths on U.S. highways, especially for younger drivers.

Addressing these challenges will take the transportation community's best thinking and the deepest commitment as a Nation. Each year, literally thousands of highway safety activities occur around the country, including educational programs, emergency medical services responses, roadway improvements, and traffic enforcement. Because safety is so encompassing, it is extremely important that the transportation community take a comprehensive, strategic view that brings together a focus on the driver, the vehicle, and the roadway. As Federal Highway Administrator Victor Mendez has said, "Safety is the umbrella under which all of our actions must fall. It is and must continue to be our first concern and our first priority."

Fortunately, the State highway safety plans (SHSPs) already provide a foundation to build upon. The development of SHSPs has demonstrated the tremendous benefits that emerge when safety partners work together and take a data-driven approach to defining strategies to address their most serious safety concerns. At the national level, the American Association of State Highway and Transportation Officials (AASHTO) developed a Strategic Safety Plan nearly a decade ago with participation from more than 30 partners. This plan contains 22 specific safety focus areas and has served as a framework for dozens of individual actions.

With a new administration, new authorization legislation on the horizon, and new technologies emerging, the time is ripe to take a fresh look at how to further strengthen the Nation's strategic focus on reducing deaths and serious injuries on U.S. roadways. Doing this will require the contributions and participation of a broad range of stakeholders and partners in identifying where to best focus the collective energy of the Nation, and then developing a roadmap to get there. To begin this process, USDOT and AASHTO recently began soliciting ideas for a national strategic highway safety plan, how it should be developed, and, ultimately, what it needs to address. Opportunities to participate in this process will be announced over the next year.

There is still much to be done to significantly reduce the suffering caused by crashes on U.S. roads. The Federal Highway Administration is ready to work with States, local governments, and the public to rise to the challenge of improving safety, knowing that everyone has a role to play in making America's roads safer.

Joseph S. Toole
Associate Administrator for Safety
Federal Highway Administration

With support from FHWA, researchers are integrating the latest camera technology with traffic control to improve safety at intersections.

Detecting Pedestrians

by David R.P. Gibson, Bao Lang, Bo Ling, Uma Venkataraman, and James Yang

(Above) Using cutting-edge cameras and computers, researchers are developing systems to detect pedestrians in crosswalks and delay traffic lights if needed to ensure safe passage for pedestrians such as these in Washington, DC. *Photo: Tim Breen for FHWA.*

In 2007, more than 4,600 pedestrians died in traffic crashes in the United States, according to the National Highway Traffic Safety Administration (NHTSA). That same year, crashes injured about 70,000 pedestrians. Zeroing in on intersections, NHTSA reports that 984 pedestrians were killed and 31,000 injured in 2005. Although these figures are lower than in previous years, the statistics underscore the continuing need for safety improvements. For instance, children 14 years old and younger accounted for 20 percent of all pedestrian injuries and 7 percent of all pedestrian fatalities. For NHTSA and the Federal Highway

Administration (FHWA), even one fatality or injury is one too many.

As part of the U.S. Department of Transportation's Intelligent Transportation Systems (ITS) program, FHWA is conducting research and development of vehicle safety and driver information systems. For many systems and applications—such as IntelliDrive℠, traffic control, security monitoring, and pedestrian counting and flow analysis—pedestrian monitoring could add value. Specifically, monitoring can help avoid potential harm to pedestrians when collision avoidance measures or emergency vehicle preemptions are imposed when pedestrians are present. And, pedestrian monitoring can help reduce delays, minimize fuel consumption, and limit vehicle emissions by facilitating traffic control optimization when pedestrians are absent.

Even after decades of research, pedestrian detection at street intersections remains a challenge. Despite the variety of existing technologies, including microwave radar; video image processing; and ultrasonic, acoustic, passive infrared (IR), active IR, piezoelectric, and magnetic sensors, these approaches have yet to excel in detecting pedestrians in real-world applications. The limitations of pedestrian sensors are largely due to the highly dynamic backgrounds typical of intersections. Variable weather and illumination conditions, for example, make it difficult to design system features and templates suitable for all situations. The high false alarm rate—that is, detecting pedestrians who are not really there—associated with these technologies has kept traffic engineers from deploying them on a widespread basis.

But the tide might be turning. Using funding available through the FHWA Small Business Innovation Research (SBIR) program, researchers have developed a new stereo vision-based approach for detecting pedestrians at intersections. The technique involves a prototype of a new IR, light-emitting diode (LED) stereo camera that can detect pedestrians both during the day and at night. The researchers also developed advanced pedestrian detection algorithms that enable them to extract generic three-dimensional (3–D) features from a stereo disparity map, leaving the human figures behind. The technology can discriminate pedestrians from vehicles because automobiles appear basically flat, while human bodies have concave shapes.

With support from the Massachusetts Highway Department (MassHighway), the researchers installed the prototype camera system at the busy State highway intersection of Route 9 and Route 47 in the town of Hadley, MA, for testing over a 3-week period. The results from this pilot test indicate that the prototype is on track toward being ready for commercial sale and widespread use.

"The pedestrian detection application using computerized stereo vision has great potential for improving pedestrian safety," says Subramanian N. Sharma, chief of engineering and research at the New Hampshire Department of Transportation's (NHDOT) Bureau of Traffic, who has been monitoring the progress of this research.

Intelligent Traffic Signal Management

At signalized intersections and midblock crosswalks, pedestrians use pushbuttons to make service requests, that is, to request the WALK signal. Once a request is granted, pedestrians can safely cross the street. But in many cases, after pressing the button, pedestrians do not wait for the signal but instead cross the street when they see a break in the traffic flow. When the crosswalk signal finally turns to WALK, pedestrians might no longer be in the crosswalk, and vehicles end up needlessly stopped. When pedestrians do wait for the WALK signal, they might cross the street quickly, also leaving stopped vehicles idling for no reason.

A reverse situation also can occur. The service time for crosswalk signals often is fixed. However, slow-moving pedestrians such as children or senior citizens might need more time to cross a street than was preconfigured in the system. In these cases, the crosswalk service time should be extended to improve safety.

Both applications—reducing and extending crosswalk times—require a pedestrian-monitoring device at the intersection, such as the one the researchers developed and tested during this study to develop a new, robust system to detect and track multiple pedestrians. When the device detects pedestrians in the crosswalk, it sends a signal to the traffic signal controller, which in turn extends the pedestrian walk phase.

According to the manual for the Econolite ASC/3 traffic signal controller used for this research project, once the normal walk time is set, if a pedestrian is detected, the walk time will be extended until (1) the maximum walk time is reached, (2) the elapsed length of the walk extension plus the pedestrian clear time equal the maximum in effect, or (3) the detector input goes to false, meaning there are no pedestrians in the crosswalk. As long as pedestrians occupy the crosswalk, the traffic signals remain red on the potentially conflicting approaches designated by the traffic engineer. When the pedestrians no longer occupy the crosswalk for a short time, the device sends another signal to the traffic controller, which can then change the signal phase to the next appropriate phase for vehicular traffic.

Pedestrian Intervals and Signal Phases

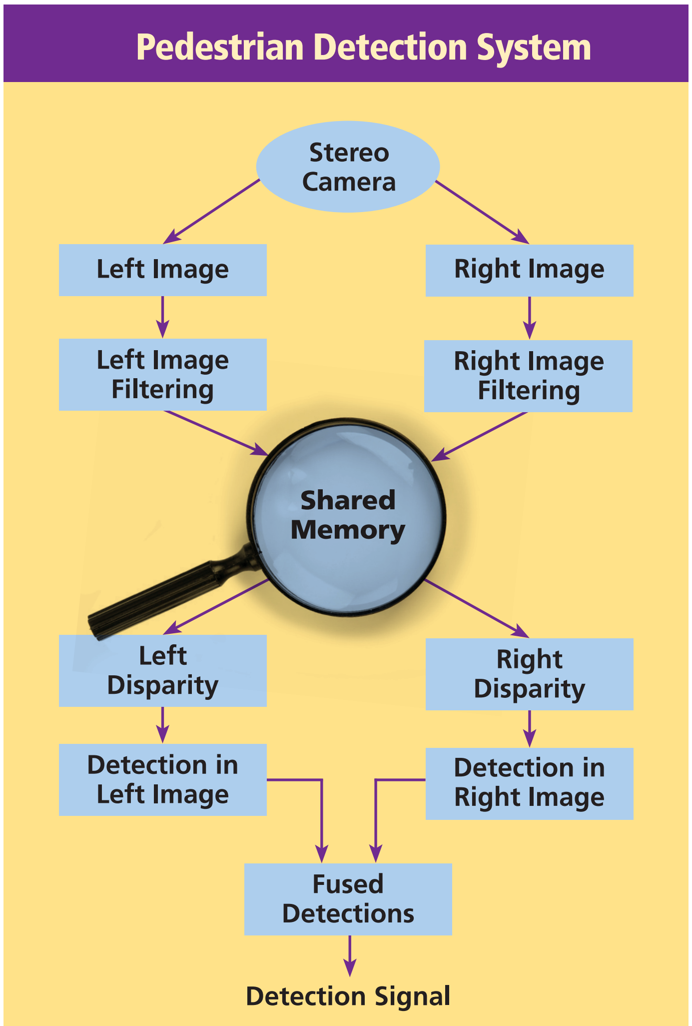
Excerpted from the 2003 edition of the Manual on Uniform Traffic Control Devices *(MUTCD):*

Guidance: The pedestrian clearance time should be sufficient to allow a pedestrian crossing in the crosswalk who left the curb or shoulder during the WALKING PERSON (symbolizing WALK) signal indication to travel at a walking speed of 1.2 m (4 ft) per second, to at least the far side of the traveled way or to a median of sufficient width for pedestrians to wait. Where pedestrians who walk slower than 1.2 m (4 ft) per second, or pedestrians who use wheelchairs routinely use the crosswalk, a walking speed of less than 1.2 m (4 ft) per second should be considered in determining the pedestrian clearance time.

Option: Passive pedestrian detection equipment, which can detect pedestrians who need more time to complete their crossing and can extend the length of the pedestrian clearance time for that particular cycle, may be used in order to avoid using a lower walking speed to determine the pedestrian clearance time.

Source: FHWA.

This approach, a type of intelligent traffic signal transition logic, offers many benefits for a community. For example, it can help senior citizens and others safely negotiate the crosswalk. Intelligent pedestrian detection can reduce traffic congestion at street intersections, ease driver frustration, and reduce idling and associated fuel consumption and pollution. By contrast, many of today's intersection traffic control systems are necessarily designed for worst-case pedestrian crossing time scenarios and are not "intelligent" in the sense of being responsive to real-time situations. For example, the researchers had to redesign signal timing on an arterial to accommodate elderly pedestrians who could not safely cross the street in the allotted time, which was originally designed to meet the requirements of the *Manual on Uniform Traffic Control Devices* (MUTCD), which called for allowing a walk speed of 4 feet (1.2 meters) per second. Note that FHWA expects to change this standard to 3.5 feet (1.07 meters) per second in the future.



The flow diagram shows how the new system locates pedestrians in the crosswalk and converts the images into a signal used by traffic lights. The structure is essentially parallel because the system performs pedestrian detection from both images, instead of from a single image, with final detection made by fusing the right and left detections. *Source: Migma Systems, Inc.*

Software Components for Detection System

For automated pedestrian detection, traffic managers can employ stereo camera systems (twin cameras), wireless receivers, software algorithms, and stand-alone computers. The key issue in image capturing is sampling time. The most important issue for the algorithms is computation time. The cameras capture a new pair of samples once the computer and algorithms have completely processed the pair captured in the previous sampling. For pedestrians at street intersections, a system must capture two or three detections in 1 second to ensure proper detection.

Another approach is image differencing. Here, the same camera (right or left) takes two consecutive images, and a "difference image" is made by subtracting the two images. Image differencing is particularly suitable for detecting moving targets. In theory, stationary objects in the image background (such as buildings and streets) appear in both consecutive images, and computers can easily remove them.

However, weather and illumination changes can generate "moving objects" and shadows that cause false detections. Using image differencing alone can generate a high number of false detections. For example, on a rainy day, image differencing can produce continuous detections even when no pedestrians are in the crosswalk. But the new stereo-based approach can further discriminate the moving objects (whether true or false) using 3-D features and thus resolve the problem in practice.

In reality, however, the differencing image may retain part of the stationary objects. This phenomenon is caused by camera "noise," which is mainly related to the quality of the image-sensing device, such as the charge-coupled device used in the study. Camera jiggling and illumination changes also can cause retention of stationary objects. Camera jiggling is unavoidable. Because the stereo camera system is mounted outdoors at the street intersection, it jiggles in strong winds and other conditions. Illumination changes can alter the pixel values of two consecutive images randomly, making the still objects appear in the difference image. Noise in digital cameras is hardware-dependent (high-quality cameras are less noisy because of the electronics used) and can never be completely filtered out. Applying advanced image-filtering algorithms will not remove all stationary objects from the difference image. To solve this problem, researchers have developed an advanced image-filtering method that significantly reduces camera noise.

Compared to the image-differencing approach, detection using a single image offers some advantages. Because detection is made based on a single image, it is almost immune to camera jiggling and illumination changes. However, it is difficult to use a single camera or monocamera system to reliably detect pedestrians in an outdoor environment, such as at street intersections, largely because of dynamic variations of background and pedestrian appearance.

In the stereo camera approach, the systems usually detect pedestrians mainly based on 3-D features extracted from a disparity map (which provides the depth information of objects in an image), which can be time consuming for the system. The calculation of a full-size disparity map usually takes a few seconds, making it impossible for the system to capture two or three samples per second. Further, because a pedestrian usually occupies only a small area in the image, most disparity information in a full-size map is not even used for pedestrian detection. For example, buildings and light poles can have their own disparity maps as well. Because detecting these stationary objects is unnecessary, the stereo camera system can exclude them from the calculation of the overall disparity map, thus reducing computation time. Otherwise, the system would be unable to reach three or four detections per second using a low-cost industrial PC, which often has a slow central processing unit and limited memory.

Image Filtering

To overcome problems associated with some difference images, the researchers developed a suite of approaches to filter out glitches generated by camera noise, camera jiggling, and illumination changes. To window out moving pedestrians—that is, detect and extract them from an image—the researchers developed a new method to estimate the baseline, or threshold, noise characteristics of the camera. The pedestrian detection system adaptively estimates the threshold value (image pixels for which intensity values are larger than this threshold value are retained; otherwise, they are treated as noises and removed) from the image content, independent of the camera characteristics.

This method is essential in accurately chipping out moving objects since camera noise is not the only source causing the imperfect difference image. This method can be applied to various types of cameras. The pedestrian detection system applies the method simultaneously to right and left images acquired from the stereo camera system. Moving pedestrians are windowed out from both images as well. By windowing out the pedestrians, the system can detect when a pedestrian is in the crosswalk and delay the signal change to allow more time for the person to cross the intersection safely.

Shown here, two consecutive low-resolution images from a single surveillance camera show a woman and little girl walking through a parking lot. By subtracting the static portion of the images (the parked cars), the system can "window" out a new image of just the moving "objects" (the woman and girl), facilitating pedestrian detection. *Photo: Migma Systems, Inc.*

Disparity Map Estimation

One of the main advantages of using a stereo vision system is to relate the distance between object and camera, and the disparity obtained from two images taken by the right and left cameras. Researchers have studied disparity estimation for years, yet it remains a hurdle for those in the computer vision community. The main challenges are noises and occlusions (or blockages) in the image, fewer distinguishing textures in the search region, and depth discontinuity.

To accomplish the goal of capturing three or four detections per second, the researchers needed to avoid developing a computation-intensive estimation scheme for the disparity maps. Many academic methods, such as phase-based matching, Markov random field modeling, and dynamic programming, will not work quickly enough for near real-time pedestrian detection applications. However, the researchers' new approach offers an efficient method for estimating the disparity maps that satisfies the time constraint. In short, the researchers only estimate the disparity values for the objects windowed out and refine the disparity values using spatial correlations.

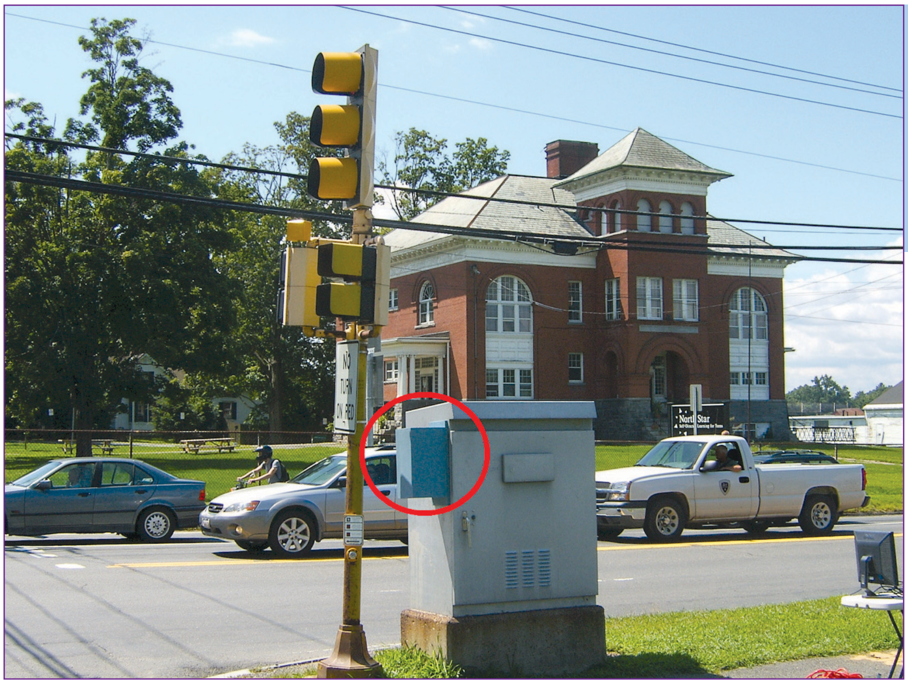
Migma Systems, Inc.

The researchers used this IR LED stereo camera, with 200 LED emitters, in the new pedestrian detection system.

Pedestrian Detection

Once the system estimates the disparity map, it can extract features from the map. Ideally, the disparity map of a pedestrian has the corresponding parts of the pedestrian, such as head, upper body, and legs. However, due to camera noise, camera jiggling, and illumination changes, the disparity map of a pedestrian is often disconnected or sometimes incomplete. Therefore, the system has difficulty extracting human body shapes from the map. Also, range information alone is not sufficient to discriminate between a moving vehicle and a walking pedestrian.

To overcome this challenge, the researchers developed a set of 3-D features from the disparity map. The features reflect the geometric differences between moving pedestrians and moving vehicles or other images caused by camera jiggling or illumination changes. However, disparity alone is not enough to accomplish the goal of near zero false detections. In addition to including 3-D disparity maps, the researchers also designed the system to extract features, which can be



Migma Systems, Inc.

At the field test intersections, researchers mounted the two receivers and antenna, which receive the signals from the wireless IR LED cameras, inside a wooden box on the side of the traffic controller cabinet. The box is circled in red.

used to categorize 3–D objects as either pedestrians or nonpedestrian, from color images and use them in pedestrian detection and discrimination. Simply put, the color of a vehicle body, for example, often is uniformly distributed, while a person's clothes tend to have mixed colors, thus facilitating distinction between vehicles and pedestrians.

IR LED Stereo Camera

The IR LED stereo camera used in this study consists of two stand-alone cameras paired together. The stereo system captures images during all illumination conditions. The cameras provide high-resolution color images during the day and, gray-scale pictures in low-light conditions such as evening and night. The cameras use a high-resolution, 0.33-inch (0.85-centimeter) color, charge-coupled device and operate at 5.8 gigahertz. One hundred LED emitters in each camera make it possible for the system to detect pedestrians 80–100 feet (24–30 meters) away in total darkness.

To construct the stereo camera, the researchers positioned the two IR LED cameras side by side, such that the two focal rays of the lenses are parallel and perpendicular to the stereo baseline, and the image planes of both lenses are colinear. This arrangement ensures that the system can estimate the disparity map accurately.

Field Trial at a Highway Intersection

With assistance from MassHighway District 2, the researchers installed the prototype at a State highway intersection in Hadley, MA, for the 3-week field trial. Workers placed a mini-PC hosting all the detection algorithms inside a nearby traffic signal controller cabinet. The system configuration for this field trial included two wireless receivers and a wireless air card that received images from the stereo camera and provided wireless Internet access. Because the metal traffic controller cabinet blocks the wireless signals, the researchers placed the receivers and wireless card in a wooden box mounted beside the cabinet. They connected a separate underground power cable to the stereo camera through the inside of the traffic light pole, essentially invisible to the public.

The researchers designed the system to recover itself from power and Internet communication failures. They implemented a mechanism to track the operation status of the mini-PC, whereby the system sent a "heartbeat image" to a Web server every 5 minutes. Each heartbeat image was a snapshot of the crosswalk at the moment it was sent. From this image, the researchers could determine whether the system was operating properly,

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This photo shows the traffic controller cabinet diagonally across the intersection (left) and the wireless stereo camera (right), both highlighted by orange circles.

detect interference between the wireless camera and its receiver, decide whether the wireless card was working properly, and assess weather conditions at the test site.

During the field trial, one camera in the stereo camera system recorded an image every 2 seconds during four predetermined, 2-hour periods: period A, 7–9 a.m.; period B, 11 a.m.–1 p.m.; period C, 4–6 p.m.; and period D, 8–10 p.m. The system stored these recorded images on the mini-PC's hard drive. The researchers then used the images to estimate the positive detection rate and missing detection rate. These four periods of time represent three rush hours and one night period. From the images recorded during these intervals, the researchers manually scanned through the images to identify pedestrians. Then, they checked the detections, which were also recorded. If the pedestrians present in the recorded images during the four time periods were among the images with detected pedestrians at the same time, the researchers concluded that the pedestrian detection was accurate. Otherwise, pedestrians were missed.

Evaluation of Prototype Performance

Because the study did not account for the total number of vehicles passing through the test site during the field trial, the researchers expressed the false detection rate as the number of false detections (that is, vehicles) per minute. The two intervals with the most missing detections were 8–9 a.m. and 4–5 p.m., which coincided with the local rush hours.

Other time intervals had no missing detection information because there were no independent recordings during these time intervals. One way to estimate the missing detections in these time intervals was to infer the missing detections

False Detection Rate Summary

Time Period	Detection Rate
6:00 a.m.–6:00 p.m.	1 per 63 minutes
24 hours	1 per 77 minutes

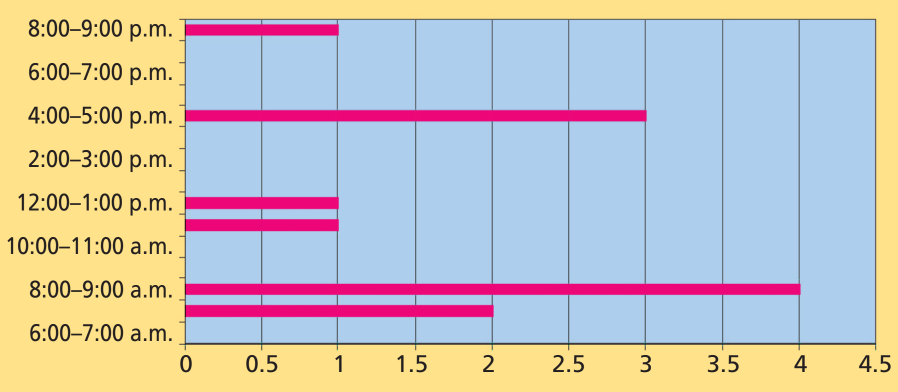
Source: Migma Systems, Inc.

Detections Made During 6 a.m.–6 p.m. and 24 Hours

	Pedestrian (6:00 a.m.–6:00 p.m.)	Vehicle (6:00 a.m.–6:00 p.m.)	Pedestrian (24 hours)	Vehicle (24 hours)
August 10	9	9	10	14
August 11	9	19	9	25
August 12	22	13	25	19
August 13	14	11	18	18
August 14	16	8	19	18
August 15	9	10	13	22
August 16	6	5	6	14
August 17	7	12	11	19
August 18	2	3	2	6
August 27	12	2	14	10
August 28	13	10	21	17
August 29	8	20	11	26
August 30	13	8	15	20
August 31	16	11	20	24
September 1	11	9	14	14
September 2	10	3	19	10
September 3	16	19	6	15
September 4	15	10	23	16
September 5	17	20	24	13
September 6	6	19	7	41
September 7	14	9	18	20
September 8	9	12	14	15
September 9	2	2	2	2
Total	**256**	**244**	**321**	**398**

Source: Migma Systems, Inc.

Missing Detections



This bar chart records missing detections for every hour from 6 a.m. (bottom of chart) until 9 p.m. (top of chart). *Source: Migma Systems, Inc.*

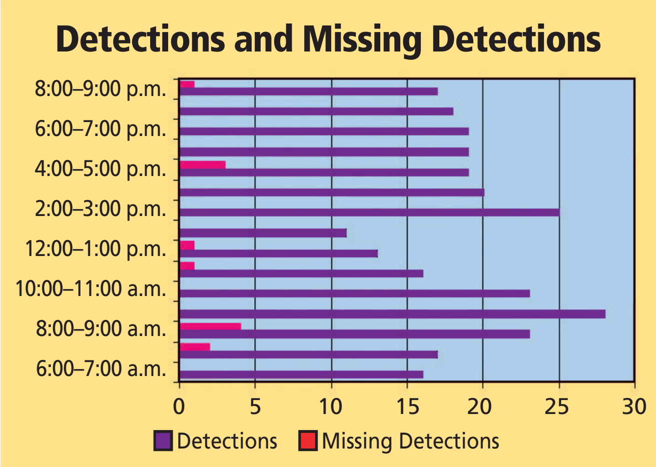
from the actual positive detections. The researchers assumed that the number of missing detections was approximately proportional to the number of actual detections during the same period. They used this rule to infer the missing detections in the time intervals in which there were no recorded images.

Using the number of missing detections (actual and estimated), the researchers estimated the rate of missed pedestrian detection as one pedestrian every 15 hours, between 6 a.m. and 9 p.m. Because few if any pedestrians crossed the intersection after 9 p.m. and before 6 a.m., the researchers concluded that the pedestrian missing rate is approximately one per day.

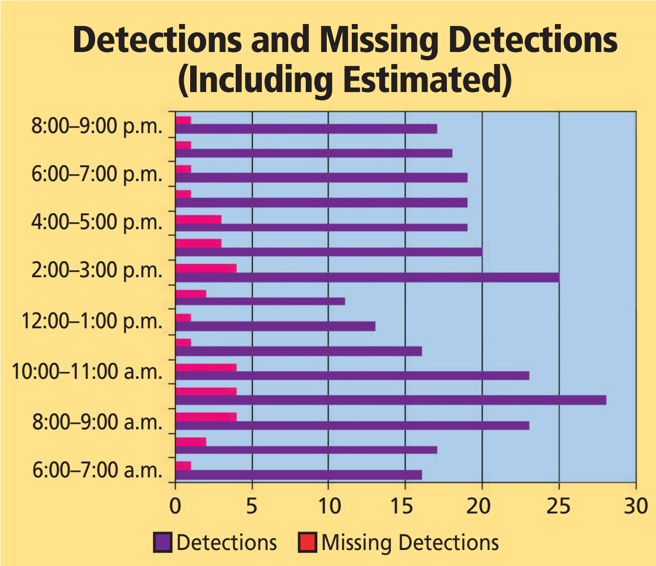
The researchers summarized the overall performance of the prototype as follows: false alarm rate = one per 60–70 minutes; pedestrian missing rate = one per day.

Representative Pedestrians

The system detected many pedestrians at the intersection, individuals and groups, during the field trial. For example, the system detected a pedestrian walking with a cane. Detection of slow-moving people is important because they might require extended service times to walk across the street safely.



This bar chart records detections and missing detections for every hour from 6 a.m. until 9 p.m. The researchers counted the missing detections from images recorded during four predetermined intervals. *Source: Migma Systems, Inc.*



This bar chart records detections and missing detections for every hour from 6 a.m. until 9 p.m. For the time intervals other than the four predetermined ones, the researchers estimated the missing detections using the new method they developed. *Source: Migma Systems, Inc.*

The system also detected children with bicycles crossing the intersection. This ability is extremely important for protecting the safety of children. Although pedestrians generally are difficult to detect at night using regular video cameras, the IR LED stereo camera developed by the researchers was able to detect pedestrians in the dark. And, in early morning and late afternoon, pedestrians often cast long shadows that make it difficult to detect them accurately. But, again, the researchers' system overcame these challenges.

Product Development

With the field trial completed, the third phase of the project, product development, is now underway. In the current prototype, all detection algorithms are executed by the mini-PC placed inside the traffic signal controller cabinet. In the final product offering, the IR LED stereo camera will host the detection algorithms. Moreover, the smart stereo camera will support Wi-Fi wireless communication, making it an Internet protocol (IP) IR LED stereo camera that overcomes the difficulties of disparity estimation caused by IP packet random delays. (The commercial IP camera has a random delay, so it is impossible to acquire two images simultaneously using two stand-alone commercial IP cameras. Therefore, the disparity map cannot be estimated using these IP cameras. In this study, the researchers acquired the images from two IR LED cameras to avoid the random delays. Detection results are transmitted wirelessly using TCP/IP.)

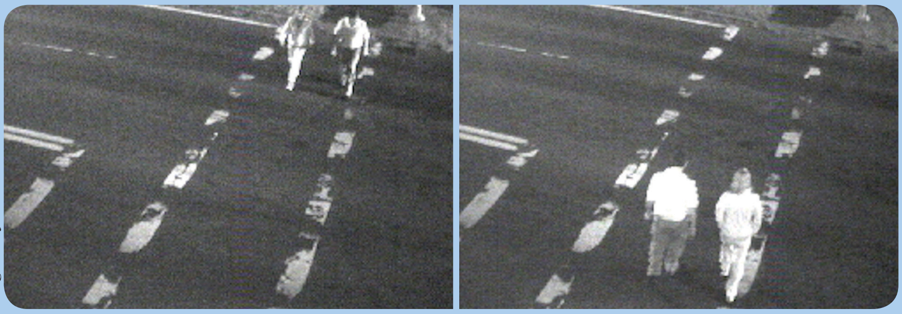
Phase three funding also will facilitate product prototyping and manufacturing. FHWA will carefully balance the mechanical design of the product and its cost to make the final product affordable for widespread deployment. The researchers expect that the final product would cost less than $3,000.

Migma Systems, Inc.

During the field trial, the IR LED stereo camera captured this 256- by 192-pixel-resolution color image of a pedestrian walking slowly with a cane.

These photos are actual 256- by 192-pixel-resolution color images from the stereo camera showing a child on a bicycle (right) and, later, three children walking their bicycles across the intersection (far right).

Migma Systems, Inc.



Migma Systems, Inc.

These gray-scale infrared images demonstrate the camera system's ability to detect pedestrians at night. (Far left) A couple crosses the intersection toward the camera; (left) a couple walks away from the camera.

The system is capable of distinguishing pedestrians from the long shadows they cast in the morning and evening. (Right) The camera captures a man walking toward it and (far right) a woman and child walking away from the camera.

Migma Systems, Inc.

And what of the ultimate, long-term value of this research? Says Dan Stewart, manager of the bicycle and pedestrian program at the Maine Department of Transportation, "This initiative has the strong potential to improve pedestrian safety and reduce injuries and deaths, as well as improve traffic flow."

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NDE Showcase for Bridge Inspectors

by Frank Jalinoos

FHWA offers a new 1-day seminar on nondestructive evaluation methodologies to help State DOTs improve routine and special testing of steel and concrete bridge components.

Approximately 600,000 bridges support, carry, and connect public roadways in the United States. These structures are critical components in a surface transportation system that is expected to support a thriving economy, provide for safe and efficient mobility, and ensure a high level of national security by facilitating rapid responses to emergencies, attacks, and natural disasters. These bridges and roads also serve as a conduit for a variety of personal travel needs, helping to ensure a satisfactory quality of life in the United States.

The Federal Highway Administration (FHWA) and State departments of transportation (DOTs) need a focus on improving the condition of the Nation's bridges through enhancement of current asset management practices, bridge inspection programs, and preservation strategies. Needed are improved quality of bridge inspection data, bridge management system implementation, and movement toward a more risk-based, data-driven method of oversight. These efforts are important in enhancing the Nation's bridge safety.

The requirements for periodic inspection of all bridges on public roads are well established and codified in regulations within the National Bridge Inspection Standards (NBIS). The 2004 legislation was in part a response to a series of major bridge failures over four decades.

(Above) A new FHWA seminar in nondestructive evaluation tests helps bridge inspectors maintain the safety of structures like this one in Woodbridge, VA.

According to the NBIS, all publicly owned highway bridges (including culverts) located on public roads in the United States that are longer than 20 feet (6 meters) must be inspected at least once every 24 months.

The standards also describe the necessary qualifications of the persons who serve as program managers and team leaders performing the onsite inspections. For both positions, the NBIS require some appropriate form of professional accreditation or a minimum number of years of experience inspecting bridges. In addition, inspectors need to complete Safety Inspection of In-Service Bridges (FHWA-NHI-130055), a comprehensive, 2-week training on bridge inspection offered through FHWA's National Highway Institute (NHI).

In addition to the NHI course, FHWA continues to develop other training to help ensure that bridge inspectors have the knowledge to perform both routine bridge inspections and assessments of structures with critical features or components of concern, such as fracture-critical members and bridges needing underwater inspections for substructure components.

In 2008, the FHWA Office of Infrastructure Research and Development (R&D), in cooperation with FHWA field offices and State DOTs, identified a need for training on nondestructive evaluation (NDE) testing to improve the quality and accuracy of bridge inspections at the State level.

A 2008 white paper, published by an ad hoc group consisting of the American Society of Civil Engineers' Structural Engineering Institute and the American Association of State Highway and Transportation Officials, echoed this conclusion. Specifically, the paper identifies the education of bridge owners and inspectors on readily available NDE technologies and their applications as a short-term research need.

"DOTs are always looking for more efficient and cost-effective tools and techniques to augment their current bridge inspection and evaluation," says Dr. Sreenivas Alampalli, P.E., director of the New York State DOT's Bridge Evaluation Services Bureau, chair of the ad hoc group, and a participant in FHWA's new seminar for bridge inspectors. "With improved inspection and evaluation tools, the overarching goal is safer bridges at reasonable costs resulting from better bridge management."

In terms of training, State bridge inspectors typically face three key problems. First, opportunities for training are sometimes limited due to budgets for training and associated travel. Second, offsite training programs commonly used by State DOTs can result in fragmented training of inspectors. Third, sending groups of inspectors to different training sessions at different times can result in wide variations in the information and experiences gained.

To overcome these challenges and meet the expressed need for NDE training, FHWA developed the Bridge Inspectors NDE Showcase (BINS) program. BINS is an informal, 1-day, demonstration-based seminar designed to expose State DOT bridge inspection staff to basic NDE tools. The purpose of the showcase is to familiarize bridge inspectors with various NDE methodologies; provide them with the knowledge of how, when, and where to apply NDE tests during a bridge inspection; and acquaint them with the capabilities and limitations of each methodology.

Types of Bridge Inspections

The typical bridge inspector, either a State DOT employee or a private consultant, is trained and qualified to perform the initial and routine inspections required by the NBIS. The NBIS describe five types of bridge inspections. The initial inspection provides the structure inventory and appraisal data, establishes baseline structural conditions, and identifies and lists existing problems or locations that might have potential problems.

Following the initial inspection, most of the 24-month inspections are routine visual inspections to determine a bridge's physical and functional condition. During visual inspections, inspectors typically use tools for cleaning, probing, sounding, measuring, and recording notable conditions. They use ladders or power lifts for access and small hand tools such as wire brushes and scrapers, picks and small hammers, flashlights and mirrors, magnifying glasses, and measuring tools.

To identify and characterize a small, previously observed crack in a steel member, inspectors will use dye penetrant testing or magnetic particle testing. In the first test, the inspector applies a high-visual-contrast dye penetrant to locate surface defects. Magnetic particle testing involves applying an external magnetic field or electric current, spraying iron or magnetic iron oxide particles over the magnetized specimen, and then detecting the particles under ultraviolet light. Attracted by the surface field, the magnetic particles hold on to the edges of the defect and reveal its location.

The other three types of inspections are indepth, special, and damage inspections. An indepth inspection is a closeup, hands-on inspection of one or more members above or below the water level to identify deficiencies not readily detectable using routine procedures. Inspectors also employ this method during inspection of a fracture-critical member.

The special inspection is used to monitor a known or suspected deficiency. An example is monitoring a steel member with a known fatigue crack until a repair can be completed or the bridge can be replaced.

Finally, a damage inspection is an unscheduled inspection to determine structural damage resulting from extraordinary loads (for example, from a hurricane, earthquake, or storm) or human actions such as vehicular collision.

In most cases, unscheduled inspections require application of methods that are more advanced than those used during visual inspections. Inspectors might employ NDE testing in situations where visual assessment might be inadequate to determine the severity and extent of defects or deterioration. In some situations, the persons who conduct the routine 24-month inspections required by the NBIS are not trained in the application of other NDE testing methods.

NDE Tests for Steel Bridges

Many kinds of NDE methodologies are available for inspectors to apply in specific circumstances to enhance their ability to identify, locate, measure, and characterize deterioration, localized damage, or a flaw in a bridge member or component. Familiarity with the capabilities and limitations of each type of NDE test, plus the appropriate times when they can be applied, could enhance the effectiveness of DOT inspectors.

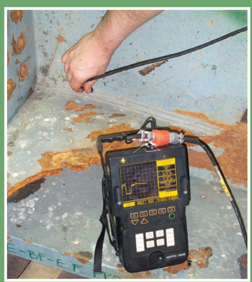
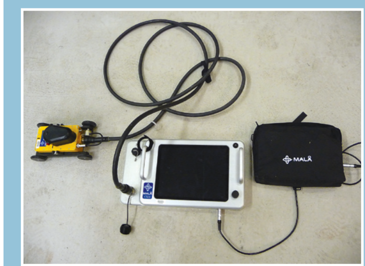
This bridge inspector is conducting ultrasonic testing (UT) on a steel bridge.

Certain types of problems are common to bridges that are of similar material and design, or that have similar details. Bridges that have steel superstructures (steel girders and girder connection members and details) can be susceptible to cracking caused by flaws in weld zones, high-stress locations, and components prone to damage through fatigue. In the early stages, these cracks might be difficult or impossible to detect using only visual inspection. Characterizing the cracks in terms of size, depth, and orientation might be difficult as well. Two well-known NDE technologies are available to identify, locate, and assess these cracks.

Typical Bridge Elements and Inspection Practices

Bridge Element	Main Concerns	Standard Practice	NDE Tools
Concrete Deck	Delamination/ Rebar Corrosion	Chain Drag/ Hammer	• Ground Penetrating Radar • Impact Echo • Infrared Thermography
Pins/Hangers/Eye Bars	Fatigue Cracks	Dye Penetrant/ Magnetic Particle	• Ultrasonic
Steel Girders/Trusses	Fatigue Cracks	Dye Penetrant/ Magnetic Particle	• Eddy Current • Ultrasonic • Infrared • Radiography • Acoustic Emissions
Concrete Pre-Stressed Girders	Strand Corrosion	Hammer	• Magnetic Flux Leakage • Strain Gauges
Concrete Post-Tensioned Girders	Corrosion, Grout Voids	Hammer	• Impact/Ultrasonic Echo • Ground Penetrating Radar
Bearing	Movement, Lack of Movement	N/A	• Tilt Meters • Remote Sensor Bearings
Concrete Columns	Rebar Corrosion	Hammer	• Ground Penetrating Radar • Ultrasonic Pulse Velocity
Foundation	Integrity and Scour	Probing	• Sonar • Crosshole Sonic Logging • Time Domain Reflectometry • Parallel Seismic

Comparison of Representative Technologies Used in BINS

Method	Advantages	Limitations
Ultrasonic Testing (UT) 	UT makes use of mechanical vibrations similar to sound waves but of higher frequency. Used for pin inspection, penetration welds (plate girder flanges, circumferential welds in pipe, etc.), length and thickness measurements.	Surface condition is critical. Permanent record has limited value.
Eddy Current (EC) 	EC can detect near-surface defects through paint.	Magnetic properties of weld materials can influence results. Orientation of probe during scanning can affect results.
Ground Penetrating Radar (GPR) 	GPR is a technique that utilizes electromagnetic waves to examine concrete and other nonferrous materials. GPR is used for detection of embedded metals, thickness of materials, mapping of reinforcement location, and depth of cover.	Environmentally sensitive to the presence of moisture, road salts, electromagnetic noise.
Impact Echo (IE)/Pulse Echo  *Olson Instruments, Inc.*	IE gives information on the depth of the defect and concrete quality.	Best applied for determining member thickness.
Infrared Thermography (IR) 	IR is a global technique that covers greater areas than other test methods, making it cost effective. IR provides an indication of the percentage of deteriorated area in a surveyed region.	Proper environmental conditions are required for testing. Anomalies are difficult to detect the deeper they are in the concrete.

Ultrasonic testing (UT) uses high-frequency sound energy (ultrasonic waves) to assess cracks. UT is capable of detecting and sizing both surface and internal cracks. Inspectors apply UT on the surface of steel components, normally using it only after cleaning the steel surface of all old paint and corrosion. The ultrasonic wave travels through the steel at a velocity dependent upon the properties of the steel until a discontinuity (that is, a crack) reflects the signal back through the material to a receiver. The inspector then interprets the distance to the discontinuity after processing the signal.

Eddy current (EC) uses electromagnetic induction to assess surface flaws, material thickness, and coating thickness. EC is a current induced on a conductive material (such as a steel bridge member or component) through induction from a magnetic field. The primary goal usually is to find flaws in the material at or just below the surface. Inspectors can use EC on steel that is painted or on cleaned surfaces.

NDE Tests for Concrete Bridge Members

For concrete bridges, the most common form of deterioration and damage occurs in reinforced components that are subjected to an environment where chlorides in solution are in contact with the surface of the concrete. This contact usually happens as a result of applying deicing salts to reinforced concrete bridge decks. It also occurs when spray from vehicles on a roadway passing beneath a bridge contacts its concrete substructure or superstructure or in marine environments where saltwater or spray comes in contact with the concrete substructure or superstructure.

Another common problem is runoff from decks that passes through leaking bridge joints, contacts the tops of abutments and pier caps, and penetrates the concrete. When the chloride ions reach the level of the reinforcing steel, corrosion occurs, the corrosion products expand, and the resulting tensile forces crack the concrete. Eventually, the cracking produces a complete delamination and separation of the concrete from the component. Two well-known technologies are available to identify, locate, and assess subsurface conditions in concrete members even if no apparent distress is detectable during visual inspection of the surface.

Ground penetrating radar (GPR) utilizes electromagnetic waves to assess subsurface flaws and to image embedded reinforcement or tendons. Typically used in concrete, masonry, and timber structures, GPR technology can locate the reinforcing steel in a concrete member and infer corroded sections. The technology also can identify and characterize cracks, voids, and moisture zones. The most common application in bridges today is for surveys and inspection of the condition of bridge decks.

Impact echo (IE), or ultrasonic pulse echo, utilizes impact-generated stress waves to assess subsurface flaws and material thickness. Inspectors typically use IE in concrete and masonry structures, particularly in concrete bridge decks. The most common methods for evaluating bridge decks today are chain dragging and hammer sounding. However, these techniques have significant limitations because of their inability to detect early signs of delamination. IE can overcome the limitations of these traditional methods.

Another technology, infrared thermography (IR), measures the amount of infrared energy emitted by an object to calculate temperature. The radiation emitted by an object increases with its temperature, and the presence of a defect impedes heat flow. Inspectors use IR in all bridge types to assess deterioration, flaws, and moisture intrusion.

BINS Addresses an Acknowledged Need

In March 2008, FHWA's NDE Validation Center at the Turner-Fairbank Highway Research Center in McLean, VA, conducted a BINS presentation on these NDE testing methods. Prior to that pilot presentation, FHWA established the following goals and objectives for BINS:

- Expose bridge inspectors to some of the latest technologies related to nondestructive testing and evaluation of bridge components.
- Provide them with formal training in the basic principles and general operational procedures of five of the latest portable, technician-driven NDE technologies (ultrasonic testing, eddy current, ground penetrating radar, impact echo, and infrared thermography).
- Reinforce the importance of continuous training in the most up-to-date NDE tools.

The overall objective is a new strategy in bridge inspection that integrates basic NDE measurements into the inspection process. The purpose is to use NDE in a spot-checking capacity to supplement standard visual inspection practice. The BINS introduces technician-driven systems with which inspectors can obtain results rapidly in the field and in a format that can be incorporated directly into the inspection report. This approach improves upon traditional NDE surveying methods that require acquisition of large datasets, post-processing, and interpretation performed by experts.

The pilot BINS workshop enabled FHWA to prove the viability of delivering effective training related to NDE inspections through an informal program, demonstrating commercially available NDE tools. The next step will be to expand the workshop into an NHI seminar, which is expected to be available by late 2009.

Benefits of a BINS Seminar

FHWA developed BINS to allow presentation during a 1-day event with morning and afternoon sessions. Alternatively, instructors can present the showcase material over 2 days, with the first session in the afternoon of the first day and the second session in the morning of the second day.

The seminar includes static displays for each of the five nondestructive tests that are highlighted. The displays include functional test equipment, test samples, and tabletop posters describing setup procedures and sample testing procedures. In addition, the displays include educational posters describing operation of the equipment and examples of when to use them.

BINS addresses three typical problems faced by State bridge inspectors: (1) opportunities for training are sometimes limited due to budgets for training and associated travel; (2) offsite training programs commonly used by State DOTs can result in fragmented training of inspectors; and (3) sending groups of inspectors to different training sessions at different times can result in wide variations in the information and experiences gained.

The BINS seminar offers a number of additional benefits, including exposing inspection staff to the latest commercially available NDE tools, enabling them to see the NDE tools in operation, and providing a forum for discussion about which NDE systems may be best suited for use in a given situation and in specific States.

"The BINS workshop makes this important training more accessible to a larger number of bridge inspectors in the States, while also producing real cost savings and improved productivity in terms of reduced expense and travel time," says Barton Newton, State bridge maintenance engineer for the California Department of Transportation (Caltrans). "Caltrans currently utilizes many NDE techniques and will be exploring the possibility of this training to provide our bridge inspectors with the latest state-of-the-art uses of NDE techniques."

The BINS workshop instructors travel to the host State to make the presentations. Up to 100 people can participate in each workshop. Interested State DOTs should call NHI for costs and to schedule the training. The inspectors at the New York State DOT are already using the NDE tools that they encountered in the BINS program in their everyday practice.

"Conducting the BINS seminar at a DOT's headquarters enables the States and Federal agencies to maximize participation and thus improve their bridge inspections," adds Gary Jakovich, bridge engineer for the FHWA Eastern Federal Lands Highway Division.

Frank Jalinoos is program manager for FHWA's NDE Validation Center. He oversees a broad program in NDE of both concrete and steel bridges. His other research areas include foundation and pavement NDE and structural health monitoring. Jalinoos holds a master's degree in geophysical engineering from the Colorado School of Mines.

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Advances in Wildlife Crossing Technologies

Researchers are deploying the latest tools to reduce animal-vehicle collisions and save the lives of both motorists and critters.

by Mary Gray

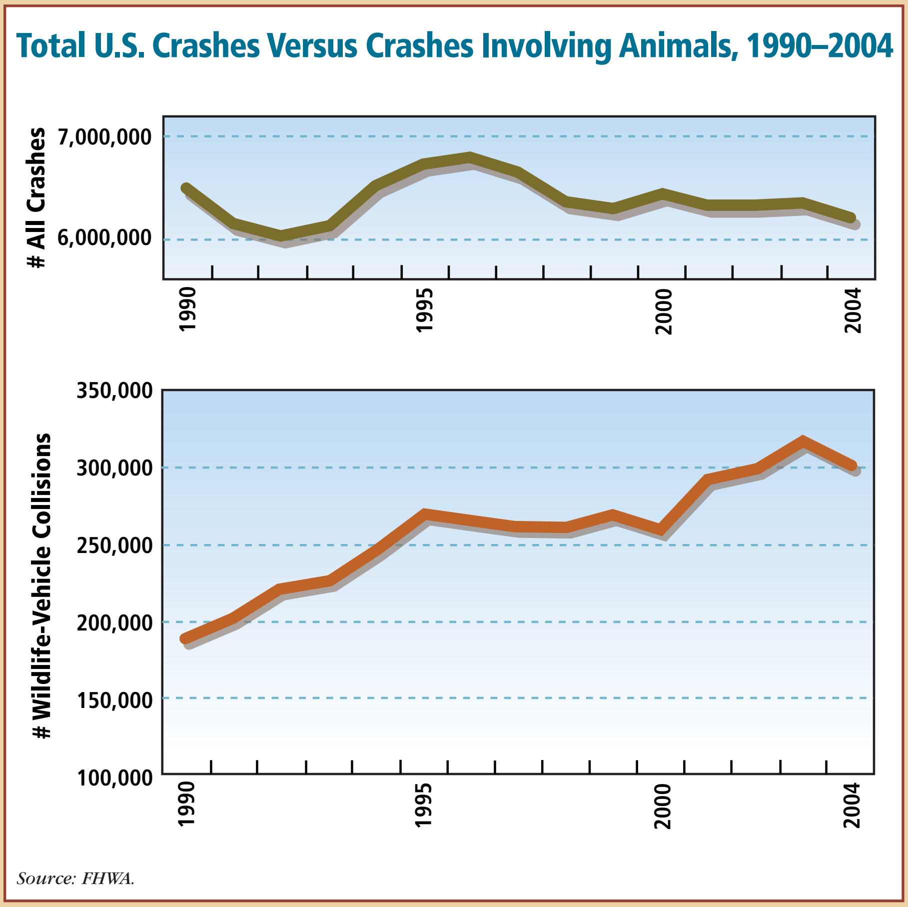
America's highways enable people and products to travel to every corner of the country. Along the way, these roads pass through the habitats of many wildlife species. Where roadways cross paths with foraging and migration routes, collisions occur—and in greater numbers than might be readily apparent.

(Above) Crashes involving wildlife and vehicles are becoming a major safety concern. Wild animals, like this elk, are attracted to roadside vegetation, often putting them in harm's way.

According to the Federal Highway Administration (FHWA), the number of reported motor vehicle crashes between 1990 and 2004 held relatively steady at slightly more than six million per year. By contrast, the number of reported animal-vehicle collisions (including wildlife and domestic animals) increased by approximately 50 percent over the same period.

FHWA recently completed a study for the U.S. Congress looking at wildlife-vehicle collisions. According to *Wildlife-Vehicle Collision Reduction Study: Report to Congress* (FHWA-HRT-08-034), an estimated one to two million collisions occur each year between cars and large, wild animals in the United States. This presents a real danger to human safety as well as the viability of some wildlife populations.

Wildlife-vehicle collisions can have a broad range of consequences for both people and animals. The most common results are wildlife mortality, vehicle damage, secondary motor vehicle crashes, and emotional trauma for motorists. A less direct impact is travel delays. Wildlife-vehicle collisions also can require the assistance of law enforcement personnel, emergency services, and road maintenance crews for repairs and carcass removal.



Source: FHWA.

For animals, collisions with vehicles present an immediate danger to their individual survival. In addition, certain threatened and endangered species can face even greater reductions in their numbers, potentially affecting their ability to survive as a population. The FHWA study documents 21 federally listed threatened or endangered animal species in the United States for which road mortality is a threat to survival of the species or population.

Reducing these collisions continues to pose a challenge for the transportation community. According to the FHWA *Report to Congress*, "State and local transportation agencies are looking for ways to balance travel needs, human safety, and wildlife conservation."

Highway agencies already are using wildlife crossings, such as overpass and underpass structures, along with installation of fencing to restrict animals to using those structures and avoiding other long segments of roadway. But certain roadway conditions such as steep rocky slopes and deep snowpack are not always conducive to installing and maintaining wildlife crossing structures and fencing. To address the limitations of these traditional approaches, researchers are pushing forward with advances and deployments in three alternative areas: animal-vehicle detection systems, activated warning signs, and electric fencing and mats. Often these technologies can be combined at one location to enhance animal detection, alert drivers, and, most important, reduce collisions.

Animal Detection Systems

Animal detection systems use sensors to detect large animals as they approach the road. The two most common technologies for detecting animals in the roadway environment are area coverage sensors and break-the-beam sensors.

Area coverage sensors detect large animals within the range of the sensor and can be either active or passive. Active coverage systems *send* a signal over an area and measure its reflection. Microwave radar is the primary technology used for active systems. Passive systems detect animals by only *receiving* signals. The two most common are passive infrared and video detection. These systems require algorithms that distinguish between moving vehicles with warm engines, moving pockets of hot air, and movements of large animals.

Break-the-beam sensors detect large animals when their bodies block or interrupt a beam of infrared, laser, or microwave radio signals sent between a transmitter and receiver.

The Colorado Department of Transportation (CDOT) is testing another sensor technology, known as intrusion detection, to reduce animal-vehicle collisions on U.S. 160 between Durango and Bayfield, CO. Military installations, prisons, airports, and some private landowners have used this particular technology for perimeter security, but its use in wildlife detection represents a new application.

The test zone consists of a cable buried 1 foot (30 centimeters)

This infrared, break-the-beam animal detection system is installed at a gap in a wildlife fence in the Netherlands.

Marcel Huijser

Detection Systems: Issues, Problems, and Operation

	Area Coverage	Break-the-Beam	Geophone	Radio Collar
False Positives				
High, moving, or wet vegetation	X	X		
Flying birds, nesting birds, rabbits	X	X		
Wind, rain, water, fog, snow spray, falling leaves	X	X	X	
Snow and ice accumulation on sensors or ground	X	(X)		
Microwave radio signal reflection off guardrail		X		
Sun, heat, unstable sensors	X	X	X	
Insufficient ventilation in box (fog on lens)	X	(X)		
Frost, low temperatures	X	X		
Lightning	(X)	X	X	(X)
Long distance between transmitter and receiver		X		
Traffic on road	X	X	(X)	
Traffic on driveways or side road	(X)	X		
Passing trains			X	
Signals from other transmitters		X		X
False Negatives				
Curves, slopes not covered by sensors	(X)	X		
Loitering animals in right-of-way not detected	(X)	X	(X)	
None of the individuals that cross have collars				X
Not feasible for nongregarious species/migrants				X
Insufficient warning time	(X)	(X)	(X)	
Some systems are only active during the night	X	X		
Maintenance				
Maintenance costs (e.g., mowing, power, fences)	(X)	X	(X)	(X)
Shade/snow on solar panels	(X)	X	(X)	(X)
Vandalism and theft (e.g., solar panels)	(X)	X	(X)	(X)
Safety (cars on road)	(X)	X	(X)	(X)
Broken sensors, warning lights, or other material	X	X	(X)	X
Period required to solve technical difficulties	X	X	X	X
Signs (standardization, liability)	X	X	X	X
No remote access to data (poor cell phone coverage)	(X)	X	X	(X)
Landscape, Ecology, Animals				
Landscape aesthetics	(X)	X	(X)	(X)
Animals' crossing areas may change over time	(X)	X	(X)	(X)
Animals may wander between fences (if present)	X	(X)	(X)	(X)
Small animals are not detected	X	X	X	X
Continuous effort to capture animals				X
Stress for the animals involved				X
Not in habitat linkage zones (light disturbance)			X[1]	

X = Problem has been reported or issue applies.
(X) = Problem has not been reported, but it could occur.
[1]For Swedish system that illuminates the road and right-of-ways once an animal is detected.

This table shows that area coverage and break-the-beam systems seem to be particularly vulnerable to false positives and false negatives. *Source: FHWA.*

deep in the roadbed. The underground cable detects changes in the Earth's electromagnetic field caused when large animals such as deer, elk, and horses cross the cable. "When an animal enters the perimeter of the test zone, a sensor transmits the detection information to a control module that activates electronic signs to warn motorists of wildlife in the vicinity of the roadway," says Marcel Huijser, a researcher at the Western Transportation Institute in Bozeman, MT. Under a research grant with CDOT's Durango office, Huijser's team and a consulting company are collaborating to investigate the reliability and effectiveness of the system.

The installation consists of 12 signs (six on each side of the highway) in the test zone. When an animal triggers the system, two signs for each direction of travel light up (the other signs are spaced out along the road). To avoid the problem of vehicles tripping the system when turning into and out of driveways, crews installed loop detectors in the pavement, like those that help ease traffic flow at signalized intersections. When vehicles drive over the loop detectors, the cable receives a message to ignore the crossing, and the signs will not light up.

Researchers also installed seven radar speed detectors to register motorists' speed when approaching the test zone and once inside it in order to monitor their base and reaction speeds. The radar system also will track traffic counts for followup analyses of the data. The researchers will download the data periodically and transmit the information to CDOT for review.

Other detection techniques include geophones that record vibrations in the ground when large animals approach, buried sensors that record changes in the electromagnetic spectrum when a large mammal walks by, and radio collars combined with receivers located in the roadway right-of-way.

According to the FHWA report *Best Practices Manual: Wildlife Vehicle Collision Reduction Study*, the effectiveness of animal detection systems in reducing collisions involving large mammals has been estimated at 82–91 percent, with an average of 87 percent. To ensure that the detection system functions reliably over time, the highway agency should establish a management plan that includes regular checks of the system's basic functions. Local personnel from the transportation or natural resource agency could perform these checks as part of their routine tasks. Remote access to the system via Internet or phone to download and check detection data, as well as data on battery voltage and output of solar panels, could help simplify this job. Periodic visits to the site still are necessary, however, to check on the functioning of the flashing warning lights and the continued correct positioning of the warning signs.

Other maintenance strategies might include a change in the management of the vegetation in the right-of-way (such as more frequent mowing or clipping), slower speeds for snowplows to avoid physical damage to the detection and warning systems from snow and ice spray, and replacing faulty, damaged, or missing equipment.

For these systems to be effective, road managers need to inform the traveling public about the purpose and location of animal detection installations. Signs placed upstream from the installations and messages transmitted via highway advisory radio are common ways to deliver the information to drivers.

In the future, this type of information might be delivered to onboard computers installed inside vehicles, which would automatically alert the driver through a warning signal when the vehicle comes within a certain radius of an animal detection system. This procedure would require a two-way, global positioning system-based communication system.

Pros and Cons of Animal Detection Systems

These systems are less restrictive to wildlife movement than fencing, and they allow animals to use existing paths to the road or to change them over time. Unlike wildlife crossing structures, which usually are limited in number and rarely wider than 164 feet (50 meters), animal detection systems have the potential to permit safer crossing opportunities for large wildlife anywhere along the outfitted roadway. Also, crews usually can install animal detection systems without major road construction or lengthy traffic control.

Some factors that affect installation time include whether fencing is part of the installation; whether roadwork is required, for example, to install a grate or electric mat; and how remote the site is. In terms of cost, these systems are likely to be less expensive than installing crossing structures, especially once the market demand grows and ushers in economies of scale through mass production. Because these technologies have not been extensively deployed and are still a relatively new approach, the cost of long-term maintenance is not known at this time.

Currently, these technologies only sense large animals, such as deer, elk, and moose. Smaller animals are harder to detect, and these systems do not warn drivers about their presence on or near the road. (There are many other solutions to minimize animal-vehicle collisions involving smaller animals, such as fencing, which is often combined with culverts to maintain habitat connectivity.) Some types of detection systems activate only in the dark, so animals crossing the roadway during daylight hours might not be perceived, leaving motorists with a false sense of security.

Environmental conditions and the size of the species can influence the reliability of animal detection systems. Road managers should consider the site carefully and the size of the target species before selecting a system. For example, break-the-beam sensors require unobstructed space between the sensors. Rocks, trees, or low-lying vegetation in between the sensors could lead to false readings.

For more information, see the combined FHWA/Montana Department of Transportation report *The Comparison of Animal Detection Systems in a Test-Bed: A Quantitative Comparison of System Reliability and Experiences with Operation and Maintenance* (FHWA/MT-09-002/5048), available at www.westerntransportationinstitute.org/documents/reports/4W0049_Final_Report.pdf.

David Bryson, ElectroBraid

This solar-powered, animal-activated warning sign is part of an at-grade wildlife crosswalk near Payson, AZ. It warns approaching motorists when elk or deer are in the vicinity.

Rhonda Stankavich, Pennsylvania DOT

This activated warning sign is installed along U.S. 191 in Yellowstone National Park, MT.

Installation and Potential Applications

When installing animal detection systems, the sensor beams need to be set at the appropriate height for the species. For example, sensors for deer that are installed too close to the ground might detect small animals too, leading to false positives. In addition to system reliability, other factors to consider when choosing a detection system include robustness (that is, consistent performance over time and low monitoring and maintenance), size of the equipment (landscape aesthetics), and the length of road the sensors will need to cover.

DOTs can deploy animal detection systems as stand-alone mitigation measures or in combination with other strategies. Typical applications could include the following installations: (1) over relatively long road sections without wildlife fencing, (2) in a gap with extensive wildlife fences on either side, (3) in a gap with limited wildlife fences on either side aimed at funneling the animals toward the road section with the detection system, (4) at the end of extensive wildlife fencing, (5) at the end of extensive wildlife fencing aimed at funneling the animals through an underpass, and (6) along a low-volume road that parallels a high-volume road with an underpass.

Animal detection systems can reduce the number of collisions but cannot eliminate crashes completely because they still allow large animals to cross the road at grade. Nonetheless, as reported in the FHWA study *Best Practices Manual: Wildlife Vehicle Collision Reduction Study*, available data suggest that these systems could reduce collisions to the level achieved through installation of wildlife crossing structures in combination with fencing, particularly in areas with low to moderate traffic densities.

Activated Warning Signs

Activated warning signs are another approach to help reduce animal-vehicle collisions. One type is the seasonal wildlife warning sign, which road managers install at certain times of the year when animals cross the road most frequently. Transportation and resource agencies have used activated warning signs during seasonal migrations and in high-crash locations, as well as in combination with animal detection systems.

A report by the Insurance Institute for Highway Safety, *Methods to Reduce Traffic Crashes Involving Deer: What Works and What Does Not*, describes a project in which researchers used large warning signs with battery-powered flashing amber lights at the ends of 2-mile (3.2-kilometer) and 4-mile (6.4-kilometer) roadway sections, together with smaller flashing signs at each milepost within the two sections. During three deer migration periods, when the signs were activated, the researchers found that travel speeds dropped about 8 miles per hour (13 kilometers per hour) from premigration levels. Also, deer-vehicle collisions dropped by 50 percent during the spring migration and 70 percent in the fall, compared with the three previous years.

Signs used in combination with other strategies can increase the effectiveness of efforts to minimize wildlife-vehicle crashes. For example,

This exclusion fencing for elk, deer, bear, moose, wolf, and coyote combines woven wire steel fencing at the bottom and electric fencing at the top.

Richard Lampman, ElectroBraid

An electric mat like this one can seal off potential wildlife entry points at the ends of fenced sections, at access roads, or at driveways.

Richard Lampman, ElectroBraid

where animal detection systems are installed, once a large animal is detected, warning signals can be activated to inform drivers that an animal might be on or near the road. A downside to activated warning signs, however, is that drivers could become acclimated to them and choose not to use caution. Similarly, motorists might acknowledge the warning, but, if they do not actually see an animal, they could choose not to slow down, thereby negating the purpose of the signs.

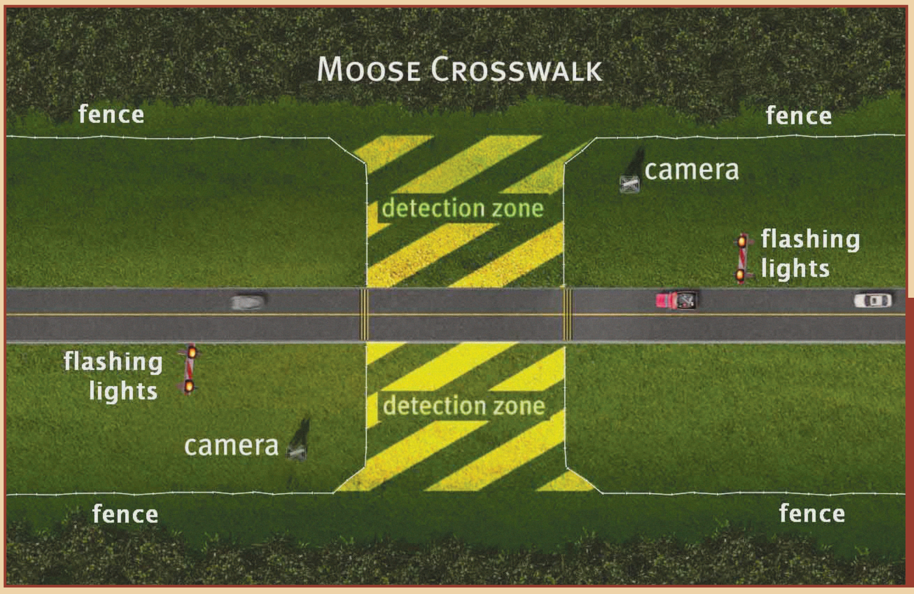
Electric Mats and Fencing

Another approach to reducing animal-vehicle collisions is installing electric fencing or mats. Field trials by the National Park Service, State resource agencies, and others have shown that electric fencing can be an effective deterrent to a variety of animals including deer, elk, and bears. An animal investigates first with its nose and then receives a painful but harmless shock, deterring it from approaching the fence again.

Similarly, electric mats, embedded in the pavement or rolled across a low-volume road, can deliver a mild electric shock when animals step on them. Electric mats serve as an alternative to costly cattle guards. Pedestrians wearing shoes and bicyclists can cross the mats safely, but dogs, horses, and people without shoes will receive a mild electric shock. According to Norris Dodd, a senior natural resource specialist with AZTEC Engineering, pedestrian crossing buttons were installed at an installation in New Mexico, so people can deactivate the mats before crossing.

Electric fencing and mats can be cost-competitive with other types of wildlife fencing or even less expensive. For example, to exclude deer, agencies sometimes install regular fencing measuring an average of 8 feet (2.4 meters) high, and some fencing is buried up to 2 feet (0.6 meter) below the ground to prevent smaller animals from burrowing under it. Electric fencing, however, could require only 4- to 7-foot (1.2- to 2.1-meter)-high construction, depending on the species of wildlife involved, according to one fencing manufacturer. Pilot installations also reveal that routine maintenance needs are lower compared with traditional fencing, as the materials tend to be more durable and resistant to rust and weathering. Electric fencing also is less visible to motorists from the roadway, so it can be an aesthetically preferable alternative for use in scenic areas.

Bushes and tree branches pushing against the fencing and fallen tree limbs leaning on electric fencing or mats could drain the power, reducing the effectiveness of the systems. For that reason, maintenance crews should walk the perimeter of electric fencing at least once a year; electric mats also need to be cleared of snow, ice, and other debris. Although the products are designed not to be



David Bryson, ElectroBraid

This diagram illustrates a typical at-grade wildlife crosswalk. On each side of the highway are an animal detection zone, a detection camera, flashing lights, and wildlife exclusion fencing. When a large animal, such as a moose or elk, steps into the detection zone, the flashing lights warn approaching drivers to slow down.

Norris Dodd, AZTEC Engineering

An elk in the vicinity of this roadway in Preacher Canyon, AZ, triggered a nearby animal detection system, which, in turn, activated this variable message sign to alert motorists. The variable message sign is approximately 600 feet (180 meters) in advance of the wildlife crosswalk, which is located about where the car is.

harmful to humans, signs should be posted to alert people to the potential hazard presented by electric fencing and mats, and deactivation buttons provide an option for people to turn them off before crossing.

Electric fencing can be used along highway rights-of-way to discourage wildlife from entering roads at unsafe locations. Electric mats could be installed on interstate ramps or near at-grade wildlife crossings. Agencies could combine either technology with animal detection systems and activated warning signs for more comprehensive applications.

Arizona Application In Preacher Canyon

In 2007, the Arizona Game and Fish Department, Arizona Department of Transportation (ADOT), FHWA, and U.S. Forest Service began a project to discourage elk and other wildlife from crossing the highway at grade along the Preacher Canyon section of State Route 260. The project aims to reduce the incidence of wildlife-vehicle collisions, while promoting wildlife highway permeability (allowing wildlife to move about freely). Researchers designed the project to integrate and evaluate the efficacy of several new technologies, including various retrofit fence designs and wildlife escape mechanisms (such as ramps, one-way trigger gates, and "slope jumps" built into the fence) to maintain the integrity of the fenced corridor. These escape mechanisms enable animals to exit the right-of-way when they inadvertently breech the fenced corridor. In particular, the study will assess the utility of animal detection systems integrated with motorist alert signage and electric fencing and mats to delineate a "wildlife crosswalk" as a potential alternative to building a costly wildlife passage structure.

After completion of a 2-year evaluation following implementation, results indicate that the project has reduced the incidence of elk-vehicle collisions by 96 percent in the Preacher Canyon area, with only one elk-vehicle collision in 2.5 years compared to 12 collisions per year from 2001–2006. In addition, the reaction from motorists in terms of reducing speed and applying brakes in response to the warning signs and crosswalk concept has been significant. "The system detected animals approaching the highway and activated the motorist alert signs 97 percent of the time, including the initial period where the bugs were being worked out," says Dodd, who was a leading proponent for habitat connectivity and decreasing wildlife-vehicle collisions while working as a research biologist at the Arizona Game and Fish Department. "We are seeing very few false positives."

At first, Dodd expected that getting motorists to respond to the activated signage would be difficult. However, motorist speeds dropped

Best Practices Manual

FHWA recently completed and posted online a comprehensive *Best Practices Manual: Wildlife Vehicle Collision Reduction Study* as a followup to the November 2007 study and report to Congress on wildlife-vehicle collisions. Congress mandated the study, report, and best practices manual in 2005 under the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users.

The best practices manual covers the complete range of strategies for reducing wildlife-vehicle collisions, from statewide and regional planning through site-specific mitigation. The document includes the following features:

- Regional and statewide tools important to wildlife-vehicle collision reduction, specifically for statewide data collection plus identification of regional priority locations.
- Guidance on incorporating collision reduction measures into roadway design by consideration of alternate alignments, possible adjustments in elements of highway design, and identification of crossing locations for mitigation efforts.
- Guidance on reducing collisions involving large animals and threatened and endangered species.
- Guidance on monitoring and evaluating collision mitigation practices.
- Checklist for implementing a collision reduction program.
- List of potential funding sources.

The manual provides design and implementation guidelines for wildlife fencing, wildlife underpasses and overpasses, animal detection systems, vegetation management, and wildlife culling.

To access *Best Practices Manual: Wildlife Vehicle Collision Reduction Study*, visit www.fhwa.dot.gov/environment/hconnect/wvc/index.htm.

Researchers installed this sign in Preacher Canyon, AZ, to alert motorists that they are approaching the wildlife crosswalk testing area. This sign is located approximately 1,500 feet (366 meters) from the crosswalk.

Norris Dodd, AZTEC Engineering

significantly—by 16 percent, or 9 miles per hour, mi/h (15 kilometers per hour, km/h)—when the signage was activated, and nearly 70 percent of all motorists showed increased alertness by applying their brakes, thus increasing their ability to avoid collisions. "Achieving this motorist response to the signage was critical to making the animal detection system and crosswalk the success it has been," Dodd says.

The lone aspect of the Preacher Canyon project that proved problematic was the proportion of animals (20 percent) that traveled around the end of the crosswalk fencing and into the fenced right-of-way along the roadway. Fortunately, no crashes resulted from this behavior while the animals fed along the roadside before returning to the end of the crosswalk zone. Although an electric mat was installed as part of the project on a low-volume lateral access road, Dodd says ADOT has approved the installation of an electric mat in the highway to discourage animals from leaving the crosswalk and walking parallel to the highway. This will be the first application of an electric mat on a relatively high-volume highway (with an average annual daily traffic volume of 8,000).

According to Jeff Gagnon, a research biologist with the Arizona Game and Fish Department, "the crosswalk and fencing will remain in place for an additional 3 to 4 years, until the site is upgraded similarly to the four-lane divided section of Preacher Canyon, allowing us to continue to evaluate the project."

Checklist for Program Implementation

As outlined in the FHWA report to Congress and a companion document highlighting best practices (see "Best Practices Manual" on page 20), a variety of approaches and techniques are available to help prevent and minimize collisions between vehicles and wildlife. Research and field trials of advanced warning signs, animal detection systems, and electric fencing and mats have proven successful under certain conditions. But success hinges on highway and resource agencies installing the devices in suitable locations, according to manufacturer's guidance, and targeting appropriate species. And the systems need to be maintained properly.

In the future, roadside animal detection systems also might transmit warning signals via in-vehicle systems to traffic approaching a location where a large animal has been detected on or near the road. With deployments of animal detection systems becoming more numerous, future research might require development and acceptance of standards for communication and integration of intelligent transportation systems.

For agencies seeking to launch programs to reduce wildlife-vehicle collisions, FHWA offers the following checklist of steps.

Establish a multiagency coalition to oversee the program. The makeup and structure of the oversight committee should be tailored to include appropriate agencies and to integrate the program within the organizational structures of the partner organizations.

Determine the baseline magnitude of the problem for the State, such as data on the annual number of collisions and crashes involving threatened and endangered species.

Implement a statewide data collection and monitoring plan and identify regional priority locations.

Establish annual goals and potential funding sources, which might include various Federal, State, and local funds as well as contributions from private foundations or corporate partners.

Identify specific improvements and mitigation strategies.

Educate State DOT staff and incorporate consideration of wildlife-vehicle collisions into the highway design process.

And establish a program to evaluate and monitor the effectiveness of specific mitigation efforts.

Mary Gray is an environmental protection specialist in the FHWA Office of Project Development and Environmental Review. She has more than 15 years of experience working on issues related to the impacts of transportation projects on the natural and human environments. She received a master's in civil engineering from Stanford University.

To access Wildlife-Vehicle Collision Reduction Study: Report to Congress *(FHWA-HRT-08-034), visit http://www.wti.montana.edu/RoadEcology/documents/Wildlife_Vehicle_Collision_Reduction.pdf. For more information, contact Mary Gray at 360–753–9487 or mary.gray@dot.gov.*

Road Safety Audits for Pedestrian Facilities

From sidewalk obstructions to inaccessible pushbuttons, RSAs in Arizona reveal common problems to watch for.

by Kohinoor Kar and Michael R. Blankenship

According to the National Highway Traffic Safety Administration, pedestrians account for nearly 11 percent of roadway fatalities. In 2007, that equated to the loss of 4,654 pedestrian lives. Improving safety and mobility for pedestrians, bicyclists, and others using nonmotorized travel modes is a critical goal of the Federal Highway Administration (FHWA) and State and local departments of transportation (DOTs).

One tool that FHWA and State and local DOTs have found effective in identifying potential safety issues and recommending countermeasures is the road safety audit (RSA). FHWA defines an RSA as a formal examination of the safety performance of an existing or planned road or intersection by an independent audit team. As described in the publication *FHWA Road Safety Audit Guidelines* (FHWA-SA-06-06), RSAs are different from traditional safety reviews in a number of key ways. First, an RSA is performed by a multidisciplinary team, including safety and design experts independent of the project, ensuring objective critiques. Another key difference is that RSAs always result in generation of a formal report.

Further, while traditional safety reviews focus primarily on vehicle traffic, RSAs broaden the scope to consider all potential road users and account for their capabilities and limitations. "A top priority for RSAs is to consider all roadway users, minimizing the unintended consequences, especially for pedestrians," says Craig Allred, a transportation specialist on the Safety and Design Team at the FHWA Resource Center.

The benefits of an RSA include the design and reconstruction of facilities that reduce the number and severity of crashes, and the reduction of costs by identifying safety issues and correcting them before projects are built. RSAs also promote awareness of safe design practices, the value of integrating multimodal safety concerns, and consideration of human factors in all facets of design.

FHWA initiated an RSA pilot project with State DOTs in 1997. Since then, the agency has completed numerous case studies on RSAs conducted across the United States. In 2007, FHWA published a series of case studies to demonstrate the effectiveness of RSAs. Arizona was chosen to participate in one of the case studies because FHWA had identified it and Phoenix as a focus State and city for improving pedestrian safety. Although all RSAs should include a review of pedestrian safety as applicable, some DOTs, including the Arizona Department of Transportation (ADOT), now are placing greater focus on pedestrian safety during their RSAs.

ADOT, which calls its RSAs "road safety assessments," established a Road Safety Assessment Program that handles RSAs statewide, including the State highway systems, county and city roadway systems, and Indian Reservation Roads. As of July 2009, ADOT had conducted 25 RSAs within various jurisdictions. The city of Phoenix has conducted several RSAs, including hosting a case study featured in the FHWA publication *Pedestrian Road Safety Audit Guidelines and Prompt Lists* (FHWA-SA-07-007), which is a pedestrian-specific guide that presents a broad overview of the RSA process and how pedestrians should be considered in that process. (FHWA completed pilot pedestrian RSAs in 2008 to test the application of these guidelines in the field, and in 2009

(Above) At this intersection, crews installed the crosswalk pushbutton between a wall and guardrail where no sidewalk exists, making access difficult for pedestrians, especially for those in wheelchairs. An RSA can help identify accessibility problems like this and recommend solutions. *Photo: ADOT.*

Master Prompt Lists for Pedestrian RSAs

Universal Considerations (For Entire RSA Site)

I. Needs of Pedestrians: Do pedestrian facilities address the needs of all pedestrians?

II. Connectivity and Convenience of Pedestrian Facilities: Are safe, continuous, and convenient paths provided along pedestrian routes throughout the study area?

III. Traffic: Are design, posted, and operating traffic speeds compatible with pedestrian safety?

IV. Behavior: Do pedestrians or motorists regularly misuse or ignore pedestrian facilities?

V. Construction: Have the effects of construction on all pedestrians been addressed adequately?

VI. School Presence: Is the safety of children in school zones adequately considered?

Topic	Subtopic	RSA Zones			
		A. Streets	B. Street Crossings	C. Parking Areas/ Adjacent Developments	D. Transit Areas
Pedestrian Facilities	1. Presence, Design, and Placement	Sidewalks, paths, ramps, and buffers	Crossing treatments, intersections	Sidewalks and paths	Seating, shelter, waiting/loading/ unloading areas
	2. Quality, Condition, and Obstructions	Sidewalks, paths, ramps, and buffers	Crossing treatments (see prompts in A)	Sidewalks and paths (see prompts in A)	Seating, shelter, waiting/loading/ unloading areas (see prompts in A)
	3. Continuity and Connectivity	Continuity/ connectivity with other streets and crossings	Continuity/connectivity of crossing to pedestrian network; channelization of pedestrians to appropriate crossing points	Continuity/ connectivity of pedestrian facilities through parking lots/ adjacent developments	Connectivity of pedestrian network to transit stops
	4. Lighting	Pedestrian lighting along the street	Lighting of crossing	Pedestrian-level lighting in parking lots/adjacent developments (see prompts in A and B)	Lighting at and near transit stop
	5. Visibility	Visibility of all road users	Visibility of crossing/ waiting pedestrians and oncoming traffic	Visibility of pedestrians and backing/turning vehicles; visibility of pedestrian path	Visibility of pedestrians/waiting passengers and vehicles/buses
Traffic	6. Access Management	Driveway placement and design along streets	Driveway placement next to intersections	Driveway placement and use in relation to pedestrian paths	N/A*
	7. Traffic	Volume and speed of adjacent traffic, conflicting conditions	Volume and speed of traffic approaching crossing, conflicting movements	Traffic volume and speed in parking lots and developments, conflicting conditions	Volume and speed of adjacent traffic and traffic at crossings to bus stops, conflicting conditions
Traffic Control Devices	8. Signs and Pavement Markings	Use and condition of signs, pavement markings, and route indicators	Use and condition of signs, pavement markings, and crossing indicators	Use and condition of signs, pavement markings for travel path and crossing	Use and condition of transit-related signs and pavement markings
	9. Signals	N/A*	Presence, condition, timing, and phasing of signals	N/A*	See prompts in B

These lists related to the needs of pedestrians in the transportation system can serve as a starting point for teams preparing to conduct pedestrian RSAs. *Source:* Pedestrian Road Safety Audit Guidelines and Prompt Lists *(FHWA-SA-07-007), http://drusilla.hsrc.unc.edu/cms/downloads/PedRSA.reduced.pdf. *N/A (not applicable) means there are no checks (prompts) for the corresponding topic.*

all pedestrian focus States received training on applying the guidelines.)

"It is rare during an RSA to find complete facilitation for pedestrian needs," Allred says. Because pedestrians are among the most vulnerable road users, RSA teams need to emphasize pedestrian safety while considering the safety of drivers, passengers, and other road users. "Pedestrian RSAs are a valuable tool to enhance walkability," he says.

Although Arizona has not conducted pedestrian-only RSAs, the State's experience indicates that vulnerable road users, such as pedestrians, bicyclists, and persons in wheelchairs, are not always accommodated in the design and construction of transportation facilities. Below, ADOT researchers share some of the typical pedestrian-safety issues they observed while conducting RSAs, highlighting key findings and a few lessons learned along the way.

Pedestrian RSAs

As noted earlier, FHWA developed national guidelines to help DOTs perform RSAs and pedestrian RSAs. These guidelines are based on literature reviews, case studies, and peer exchanges across the country and, thus, provide a systematic and formalized approach to performing facility audits.

According to the FHWA guidelines, an RSA or pedestrian RSA involves the following eight steps: (1) identify a project or existing road, (2) select a multidisciplinary team, (3) conduct a startup meeting to exchange information, (4) perform field reviews under various conditions, (5) conduct an RSA analysis and prepare a findings report, (6) present findings to the project owner or design team, (7) prepare a formal response, and (8) incorporate findings into the project when appropriate.

The guidelines for conducting pedestrian RSAs include detailed prompt lists that provide a high-level outline of the topics typically

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Members of an RSA team in Arizona spotted this pedestrian crossing a five-lane roadway midblock. He crossed halfway and waited in the center turn lane for a gap in traffic before continuing across the street.

considered at each stage and highlight areas that should be examined for safety issues. For example, when auditing pedestrian facilities, RSA teams should consider the following: the presence, design, and placement of pedestrian features; their quality and condition; their continuity and connectivity; lighting; and visibility.

DOTs can conduct pedestrian RSAs at any stage of a project, including preconstruction (planning, preliminary design, final design), construction (work zone traffic control, preopening), and postconstruction (existing road open to traffic); however, ADOT officials suggest the earlier the better from the point of view of cost effectiveness. For example, an RSA performed at the planning or preliminary design stage could be more beneficial than one conducted during construction or after the project is completed, when making changes can be costly.

Even though pedestrian considerations always should be an important element in any RSA, a pedestrian-specific RSA might be warranted for particular locations with anticipated or actual safety issues. When historical crash and injury data or engineering judgment deems specific locations to have pedestrian safety issues, an RSA might be an ideal tool.

Pedestrian Signals

While conducting RSAs on Arizona facilities, ADOT researchers discovered that some pedestrian signal locations and installations did not comply with the Americans with Disabilities Act (ADA). For example, one local agency had installed traffic signals at five intersections on a rural divided highway and included pedestrian signals. However, the agency did not provide any other pedestrian accommodations, such as sidewalks or accessible pushbutton locations. Another agency had installed a pushbutton in a location that required the pedestrian to stand between the guardrail and turning traffic, with very little refuge area.

The RSA team's recommendations at these sites included providing ADA-compliant signal installations and removing pedestrian signals until proper accomodations were installed.

Lighting

One busy urban intersection with convenience stores and check-cashing facilities on all four corners had only one street light, making it difficult for motorists to see pedestrians crossing the intersection at night. As a result of the RSA, the city is exploring options to improve lighting at this location.

Elsewhere, an RSA team visited a section of high-speed arterial in an urban area that had been the site of 14 pedestrian crashes over a 6-year period (2001 to 2006), including three fatal pedestrian crashes over a 4-year period (2000 to 2003). A convenience market, a bar, a post office, and several motels, condos, and residences are located along this section of arterial. While conducting the RSA at this location, the audit team observed a steady flow of pedestrians crossing the five-lane arterial, both during the day and at night, near an unsignalized intersection with no marked crosswalks. The closest signalized intersections are approximately 1,300 and 1,600 feet (396 and 488 meters) from the crossing location with the high volume of pedestrian traffic.

The team witnessed several pedestrians crossing at midblock just south and just north of the unsignalized intersection. Most would cross halfway and then wait in the center turn lane for a gap in traffic before continuing their crossing maneuvers. Others simply ran across the arterial, darting among moving vehicles. Local drivers might expect to see these types of pedestrian activities, but a large number of tourists also use this route and might not anticipate pedestrians in the middle of a five-lane highway.

According to ADOT's crash database and police crash reports, 79

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(Above) While conducting RSAs, the Arizona teams noticed numerous problems at sidewalks, including inconsistent and noncompliant use of truncated domes, as shown here where the dome mat is too far from the curb. Truncated domes should be placed 6 to 8 inches (15 to 20 centimeters) from the bottom of curbs to improve access for people with vision impairments.

(Below) One RSA team documented a steep dropoff, a safety hazard for pedestrians, beside the sidewalk at this drainage area.

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Here, an RSA team notes that a utility pole and an overhanging tree disrupt the continuity and accessibility of the sidewalk.

percent of the pedestrian crashes at this location occurred at night. Although one side of the road offers continuous lighting, the RSA team found it difficult to see pedestrians crossing the highway in the dark. As a part of the RSA, the team reviewed crash reports from drivers who struck pedestrians at this location and found statements including the following: "I always slow down in the area because of the lighting, and I know people cross the highway at night and it's hard to see them," and "Even with my headlights and the headlights from the vehicle in the inner lane, I still did not see the pedestrians until they were directly in front of me."

As a result of the audit, FHWA approved the use of Federal funding from the Highway Safety Improvement Program (HSIP) to implement a number of RSA recommendations to improve pedestrian safety at this location. Specifically, ADOT will conduct a lighting assessment, improve the lighting infrastructure, install an in-road warning light system with light-emitting diode (LED) pedestrian crossing signs, and put in high-visibility crosswalks and advance warning signs.

Transit Operations

In terms of transit operations and pedestrian safety, the audit teams found that some bus stop locations and transit schedules unintentionally encouraged pedestrians to make hazardous crossing movements when trying to transfer to another bus. Team members observed transit riders darting across busy streets at the intersection and at midblock locations to avoid missing their connections.

RSA recommendations therefore included relocating bus stops and adjusting bus schedules to allow more time between transfers. The team also recommended that the city explore the need for accommodating midblock crossings, including the use of two-stage crosswalks.

Sidewalks/ADA Compliance

The RSA teams also observed a number of sidewalk-related issues during the course of conducting their audits. These issues included inconsistent or nonexistent use of truncated domes (detectable warnings required by the ADA to help visually impaired pedestrians detect the boundary between the sidewalk and the street), improper ramps, steep cross slopes where sidewalks intersect steep driveways, sidewalk discontinuities at raised islands, edge dropoffs, and dropoffs at drainage facilities.

Recommendations included providing ADA-compliant accommodations such as curb ramps, truncated domes, and proper sidewalk cross slopes.

Crossing Maneuvers

During one RSA, the audit team identified a free-flowing, high-speed, right-turn lane that created unsafe crossing situations for pedestrians at an intersection near a residential area and local government office complex. The team's recommendations included realigning the right-turn lane to reduce the turning radius and, therefore, right-turn speeds.

Elsewhere, a suburban intersection with an office park, convenience store, and restaurants on the corners had a pedestrian crossing distance that included seven vehicle lanes, two bike lanes, and a median. Implementation plans stemming from the RSA include providing pedestrian countdown signals and installing a refuge area in the median.

Obstructions

The audit teams noted numerous obstructions that inhibited accessibility and sight distances for pedestrians and other vulnerable road users. Obstructions included utility and light poles in the middle of the sidewalk, trees overhanging the sidewalk, a gate installed to prohibit motorized vehicles from using a recreational trail, and vehicles parked on the sidewalk. The teams also observed instances where private property owners were encroaching on the public space by constructing walls on the sidewalk and store owners were stacking new tires and parking all-terrain vehicles on the sidewalk.

These off-road vehicles are parked on the sidewalk in front of a store, restricting pedestrian access. To address the problem, the audit team recommended enforcing the city ordinance restricting private property owners from encroaching on public infrastructure.

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Gabe Rousseau, FHWA

ADOT

(Far left) The location of the pedestrian pushbutton at this crossing was inaccessible to some users, due to the sloping pavement. (Left) Crews laid new concrete to make the pushbutton location flush with the sidewalk, improving accessibility for all users.

The audit teams' recommendations included removing the obstructions, delineating the poles with reflective bands, using bollards (metal or wood posts) instead of gates, and improving enforcement of city ordinances.

Lessons Learned

Based on Arizona's experience, a multidisciplinary approach is particularly important to ensure a well-rounded, comprehensive RSA. "Having law enforcement officials participate on the RSA team is critical to the development of safety countermeasures for pedestrians," says Karen King, a safety engineer with the FHWA Arizona Division Office, who participated in the RSAs. "They offer a unique vantage point in regard to pedestrian and driver behavior, which contributes greatly to successful problem identification and solutions."

Additional specialty disciplines might be beneficial to have on the team as well. For example, where private property owners are encroaching on sidewalks, it might help to have someone from the city planning department or code enforcement on the team. Pre-RSA coordination with the road agency requesting the RSA can help identify these issues, which in turn can guide the selection of appropriate members for the team.

Another lesson learned is the value of conducting a field review at night as part of the RSA. One local traffic engineer informed her RSA team that she never would have known about the high volume of pedestrian and bicyclist traffic using a poorly lit intersection at night without the nighttime RSA review.

A strong DOT or agency commitment to ensuring safety for all road users is important not only in identifying safety countermeasures but also in implementing them quickly. For example, when ADOT participated in an FHWA-sponsored RSA case study for the city of Phoenix, one of the audit team's suggested countermeasures was to improve the accessibility of a pushbutton for a pedestrian signal at the entrance to a high school. Before the ink had dried and the final RSA report had been delivered to the city, Phoenix's Street Transportation Department had made the recommended improvements at this location.

Also, the ADOT researchers concluded that the reactive culture of some roadway agencies sometimes stands in direct conflict with the proactive nature of an RSA. For example, some agencies do not consider a location to have a pedestrian safety issue unless a fatal crash involving pedestrians has occurred there. An RSA can help identify pedestrian safety issues before a tragedy occurs.

Although crash history is a primary method for determining where to conduct an RSA, there are other, more proactive ways to select RSA locations. For example, road agencies should consider pedestrian RSAs in locations with high pedestrian activity, such as near schools, fast-food restaurants, convenience markets, parks, post offices, hotels, and offices. Also, the local law enforcement agency can provide keen insight into problem areas that might warrant an RSA. Recognizing and overcoming the tendencies of a reactive culture could help reduce the number of pedestrian injuries and fatalities in the United States.

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ADOT acknowledges the support and resources provided by FHWA through its RSA and HSIP programs. The authors are thankful to all participants in the RSAs conducted through the Arizona RSA Program and FHWA case studies.

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Disclaimer: Any statements expressed in this article are those of the individual authors and do not necessarily represent the views of ADOT.

Along the Road

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

Technical News

Using WIM Technologies for Better Pavement Design

Obtaining quality data on traffic loading is at the heart of a new workshop developed by the Federal Highway Administration's (FHWA) Offices of Infrastructure and Highway Policy Information. The Weigh-in-Motion (WIM) and Traffic Workshop, which targets traffic and pavement design staff, demonstrates the complete process of using WIM technologies to collect data on vehicle and axle weights, axle spacing, speed, and vehicle class.

Workers install a weigh-in-motion site in southern Virginia for collecting quality WIM data.

"When designing new pavements, it is critical to have accurate WIM data," says David Jones of FHWA's Office of Highway Policy Information. "The better the WIM data that is collected, then the better the weight projections are for the future."

The free, 2.5-day event walks participants through each step of the process, starting with an overview of available WIM technologies and collection equipment. Participants then learn how to select appropriate sites and prepare the pavement for installing the equipment. Instructors also cover procedures for WIM system installation, calibration, validation, and acceptance testing, as well as data collection, processing, and validation. The workshop concludes with a demonstration of PrepME, a software tool developed by the University of Arkansas that is used to input quality data, including traffic data, into the *Mechanistic-Empirical Pavement Design Guide*. This guide is a robust tool used to estimate damage accumulation over the service life of pavement. Workshop participants receive a 444-page workbook that contains detailed information for future reference.

"These tools, made possible by the LTPP [Long-Term Pavement Performance] program, bring together the best available prediction models to assist tomorrow's designers in making quality pavement designs," says Mike Moravec, a senior highway engineer with FHWA's Pavement Design and Analysis Team. "These reliably designed pavements, together with timely and effective preservation treatments, will better serve the traveling public for decades to come."

For more information about upcoming workshops or how to host a workshop, contact David Jones at 202-366-5053 or djones@fhwa.dot.gov, or Mike Moravec at 202-366-3982 or mike.moravec@dot.gov.

FHWA Concludes Study on Pedestrian Safety Countermeasures

In 2002, FHWA awarded grants to the cities of Las Vegas, Miami, and San Francisco to deploy and evaluate pedestrian safety countermeasures. The purpose was to demonstrate how a city could improve pedestrian safety by performing a detailed analysis identifying and evaluating high-frequency crash locations involving pedestrians, observing factors such as driver and pedestrian behavior, and deploying various low-cost countermeasures tailored to specific sites. FHWA conducted an independent evaluation to compare the countermeasure deployments in the three cities.

In San Francisco's Chinatown, researchers deployed a safety countermeasure known as a "pedestrian scramble" (shown here), during which all traffic is stopped, and pedestrians are given a walk phase on all four crosswalks.

At the conclusion of the 6-year study, researchers looked at measures of effectiveness to determine if safety improved. Of the 18 countermeasures deployed, researchers identified the following 7 as highly effective: leading pedestrian intervals (allowing the pedestrian crossing phase to begin before the green phase for vehicles); pedestrian countdown signals; in-street pedestrian signs (flexible, fluorescent yellow signs typically seen on the centerline or in the median of midblock pedestrian crossings); activated flashing beacons; rapid flash beacons (rectangular beacons mounted to pedestrian signs that employ a flash pattern similar to those used on emergency vehicles); call buttons that confirm the pedestrian's press; and Danish offset (an offset used at the middle of a multilane crossing) combined with high visibility crosswalk, advance yield markings, and "Yield Here to Pedestrians" signs.

According to FHWA, the study successfully demonstrated that a locality can make targeted, low-cost improvements and have a positive effect on pedestrian safety.

For more information and indepth reports from each location, visit http://safety.fhwa.dot.gov/ped_bike/tools_solve/ped_scdproj/index.cfm.

Public Information and Information Exchange

USDOT and HUD Launch Partnership For Sustainable Communities

USDOT and the U.S. Department of Housing and Urban Development (HUD) have launched a partnership to help U.S. families access affordable housing and more transportation options with lower costs.

The average working family spends nearly 60 percent of its budget on housing and transportation costs. HUD and USDOT plan to help reduce these costs by creating affordable, sustainable communities with more travel options.

USDOT and HUD have established a high-level, interagency task force to coordinate Federal transportation and housing investments. The task force will undertake a number of initiatives to ensure that the two departments work efficiently to give Americans more choices for affordable housing near employment opportunities; more transportation options to reduce travel costs, shorten trip times, and improve the environment; and safe, livable, and healthy communities.

For more information, visit www.hud.gov/offices/cir/test090318.cfm.

FHWA Revamps National Highway Specifications Web Site

Since 2003, FHWA's "National Highway Specifications" Web site has offered a fully searchable, electronic library of information on highway construction specifications in all 50 States, Puerto Rico, the District of Columbia, and FHWA's Federal Lands Highway Offices. The site, www.specs.fhwa.dot.gov, offers an array of documents, such as standard specifications, construction manuals, drawings, innovative contracting methods, and special provisions for new and emerging materials and technologies.

FHWA maintains the site with material submitted by State departments of transportation and other agencies to ensure that it contains the most current specifications and construction manuals for each contributing transportation agency.

Recent updates simplify the uploading of information, making it easier for States to revise and add material. The improved site also features faster search capabilities. In addition, FHWA added more links to related Web sites and State standard drawings, as well as contact information for State specification engineers, accessible to State personnel with authorized administrative login access.

"As a one-stop source for specification information, the Web site has saved users time and money, while improving practices and promoting higher quality in construction end products," says Ken Jacoby, construction quality management engineer with FHWA's Office of Asset Management.

For more information, visit www.specs.fhwa.dot.gov.

Announcing: 2010 Planning Excellence Awards

FHWA, the Federal Transit Administration, and the American Planning Association recently announced the return of the Transportation Planning Excellence Awards in 2010. The purpose of the biennial program is to recognize outstanding planning initiatives across the country.

In 2008, the Transportation Planning Excellence Awards recognized 13 winners and 9 honorable mentions, including Federal, State, and local agencies and industry organizations. A complete list of the award winners and honorable mentions is available at www.fhwa.dot.gov/hep/awards.htm. The winners were recognized during the opening session of the Transportation Research Board Joint Summer Meeting in Baltimore, MD.

The Transportation Planning Excellence Awards are given to outstanding projects, processes, and groups that contribute to the evolution and advancement of transportation planning. An independent panel of judges with expertise in all areas of planning recommends award winners based on innovation; community outreach and public involvement; partnerships and collaboration; multimodalism; and equity, livability, and sustainability.

The call for nominations for the 2010 awards is scheduled for December 2009. For more information, visit www.fhwa.dot.gov/hep/awards.htm or contact Fred Bowers at 202–366–2374.

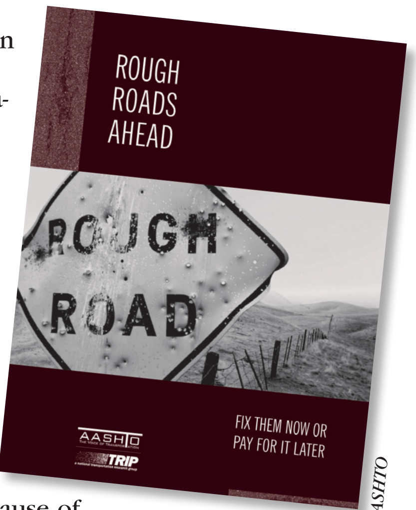
FHWA Announces Excellence in Utility Relocation Award Winners

FHWA recently announced the winners of the 2009 Excellence in Utility Relocation and Accommodation Awards, a biennial program conducted to honor outstanding achievement in the utility arena. FHWA presented awards in four categories: project development, construction management, innovation, and leadership.

The 2009 award winners showcase exemplary programs, projects, initiatives, and practices that integrate the consideration of utilities into the planning, design, construction, and maintenance of surface transportation facilities. For example, one winner transmits utility plan markups in electronic format for construction projects, thereby better facilitating project utility coordination, increasing plan quality, and reducing printing costs for both the agency and utility owners.

For more information and a complete list of award winners and their projects, visit www.fhwa.dot.gov/utilities/2009awards.cfm.

AASHTO Report Says Rough Roads Costing Motorists



AASHTO

According to a report released by the American Association of State Highway and Transportation Officials (AASHTO) and TRIP, a transportation research group, driving on rough roads costs the average American motorist approximately $350 a year in extra vehicle operating costs. Drivers living in urban areas with populations of more than 250,000 are paying upwards of $750 more annually because of accelerated vehicle deterioration, increased maintenance, additional fuel consumption, and tire wear caused by poor road conditions.

AASHTO's report, *Rough Roads Ahead: Fix Them Now or Pay for It Later*, finds that one-third of the Nation's major highways, including interstates, freeways, and main roads, are in poor or mediocre condition. The report points out that traffic growth has far outpaced highway construction, particularly in large metropolitan areas. For example, in some parts of the country, dramatic population growth has occurred without a corresponding increase in road capacity, placing enormous pressure on roads that, in many cases, were built 50 years ago. Recommended solutions include increased investment, improved management strategies, a focus on preserving essential public assets, and development of better, longer lasting materials.

For more information and to download the report, visit http://roughroads.transportation.org.

AASHTO

Centers of Innovation Sharpen Volpe Center Focus

The Volpe National Transportation Systems Center recently underwent a reorganization to better define its focus and enhance its ability to anticipate future transportation challenges and use internal and external assets to improve the Nation's transportation system.

To clarify, reinforce, and strengthen the Volpe Center's role in applying its technical capabilities to USDOT strategic goals and national transportation priorities, the center has been restructured into eight Centers of Innovation focused on the following: multimodal systems research and analysis; safety management systems; environmental and energy systems; freight logistics and transportation systems; physical infrastructure systems; communication, navigation, surveillance, and traffic management systems; human factors research and system applications; and advanced vehicle and information network systems.

According to Volpe Center officials, the restructuring will increase opportunities for research and technology synergy both within and outside USDOT and enhance the effectiveness of the Volpe Center's crossmodal and multimodal capabilities.

For more information, visit www.volpe.dot.gov.

USDOT Observes Multiyear Decline In Work Zone Fatalities

In spring 2009, transportation leaders kicked off the 10th annual National Work Zone Awareness Week with a ceremony near the Nation's capital. At the event, U.S. Secretary of Transportation Ray LaHood announced a 17

Participants talk to Joseph S. Toole, associate administrator for FHWA's Office of Safety, at a kickoff event for the 10th annual National Work Zone Awareness Week.

percent drop in work zone fatalities and injuries in 2007, the most recent year for which data are available.

This decrease represents the sharpest single-year percentage decline since USDOT began observing National Work Zone Awareness Week in 1999. This decrease continues a multiyear trend of increasingly safe work zones. There were 835 fatalities in 2007, down from 1,004 in 2006.

National Work Zone Awareness Week is a national campaign conducted each year at the start of construction season to encourage safe driving through highway construction sites. Federal, State, and local transportation officials and the public observe National Work Zone Awareness Week during the first week of April.

For more information, visit http://ops.fhwa.dot.gov/wz/outreach/wz_awareness.htm.

Program Encourages Tennesseans To Reduce Air Pollution

The Tennessee Department of Transportation (TDOT) recently launched Clear the Air Tennessee, an educational program designed to encourage Tennesseans to take action against poor air quality by changing their travel habits. The program is funded through the Federal Congestion Mitigation and Air Quality Improvement program and targets Tennessee counties designated by the U.S. Environmental Protection Agency as being in need of air quality improvement.

TDOT's program uses the acronym SIMPLE to help Tennesseans remember the steps they can take to reduce air pollution: *S* (watch your *speed*); *I* (*idle* less); *M* (*maintain* your vehicle); *P* (*plan* your trips); *L* (*leave* your car at home); *E* (*educate* others).

TDOT's "Clear the Air Tennessee" Web site offers steps motorists can take to reduce air pollution. *Source: TDOT.*

According to TDOT officials, the program hopes to mitigate the health-related impacts of air pollution, including aggravated allergies, heart disease, eye and respiratory irritation, and asthma and bronchitis. Currently, more than half of all Tennesseans live in areas where air pollution poses a health risk.

TDOT is promoting the program through messages on billboards, banners, print ads, and on television and radio. The program also operates a Web site with information on the causes of air pollution, ways to reduce individual impacts on air quality, and links to local clean air groups.

For more information, visit www.cleartheairtn.org.

TDOT

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@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).

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Internet Watch

by Alicia Sindlinger

Promoting Federal Clean Air Goals

In many U.S. cities, the automobile is a major polluter, accounting for more than 25 percent of air pollution nationwide. Two Federal laws—the Transportation Equity Act for the 21st Century and the Clean Air Act Amendments—set mobility and clean air goals for State and local governments. To garner public support to meet the requirements in the laws, the U.S. Department of Transportation and the U.S. Environmental Protection Agency developed a public education campaign known as *It All Adds Up to Cleaner Air*.

In 2008, the initiative narrowed its focus to providing free, commercial-quality educational materials and marketing tools on an improved Web site at www.italladdsup.gov. The Web site and outreach resources help to increase public awareness about the connections between transportation choices and air pollution, forming a base upon which agencies can introduce programs to reduce air pollution, such as automobile inspection and maintenance initiatives, which frequently meet with public opposition.

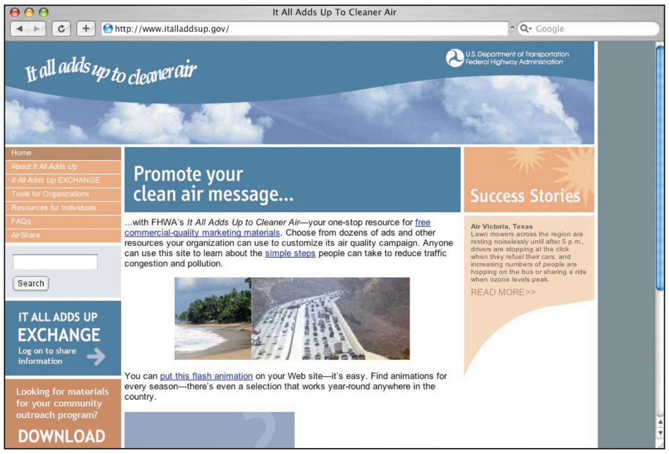
"The high-quality marketing materials are the heart of *It All Adds Up*," says April Marchese, director of the Federal Highway Administration's Office of Natural and Human Environment. "And having them available in one location, on a user-friendly Web site, provides easy access so they can continue to be used. The Web site is the most efficient means of disseminating these materials to State and local agencies."

Public Education and Partnership Building

After years of steady growth, the messages, materials, and outreach tools are being used in more than 100 communities in all but six States. The communities use a variety of approaches, from holding a children's poster contest to offering mechanic-led car maintenance tutorial sessions, demonstrating the versatility of the initiative.

Implementing *It All Adds Up* has empowered communities to establish and strengthen both traditional and nontraditional partnerships. For example, one effort in Pennsylvania brings together more than 160 partners from State and Federal governments, municipalities, hospitals, transportation management associations, and private firms. These partnerships help to leverage resources, sustain and validate the effort, and bring together best practices.

To educate the public, the messages consistently emphasize four simple, convenient actions that people can take to improve air quality and reduce traffic congestion: use trip chaining, that is, combine errands into a single car trip; keep vehicles properly maintained; refuel in the evening and avoid topping off the gas tank; and choose alternate modes of transportation, such as carpooling, mass transit, bicycling, or walking.



The *"It All Adds Up to Cleaner Air"* Web site.

Tools To Help Get It Done

Critical to the success of any air quality program is developing the necessary messages, materials, and resources. That's where the "*It All Adds Up*" Web site comes in—providing easy access to tools for educating the public and introducing effective air pollution reduction programs.

A key section of the Web site, Tools for Organizations, houses the free marketing materials, including print ads, billboards, flyers, and television commercials—even Spanish translations of many materials—which are downloadable and easily customizable. The "*It All Adds Up*" Web site also features a number of additional resources for outreach organizers. From the site's Education Center, organizers can download interactive workbooks and tutorials about how to develop a communications strategy and find tips for implementing programs by reading other communities' success stories. Site visitors also can participate in the *It All Adds Up* Exchange, where they can share ideas, opinions, and leads, help each other solve problems, and share their products.

"It's been a real lifesaver to have all of the clean air materials and information available on the Web site," says Charise Stephens, who leads a clean air initiative that reaches across the State of Georgia. "Our community members have really responded to the messages and now have a much better understanding of how their transportation choices affect the quality of the air we all breathe." Stephens' network of private and public partners has seen a significant increase in public participation since the initiative began in 2004.

Communities across the country are using *It All Adds Up* materials to customize outreach and public education initiatives that effectively communicate transportation and clean air messages to local citizens. By using the Web to connect State and local agencies to the materials, *It All Adds Up* has uncovered a formula for success—providing the resources agencies need to help their communities make wiser transportation choices, thereby improving air quality across the country.

To learn more, visit www.italladdsup.gov or contact Kathy Daniel at 202-366-6276 or kathy.daniel@dot.gov.

Alicia Sindlinger is a contributing editor for PUBLIC ROADS.

by Rachel Grant

Reducing the Impact of Roads On Stream Ecosystems

Building a roadway near a stream poses a variety of risks to the local ecosystem. Where a road alignment encroaches on the stream channel or its floodplain, construction can affect the availability and quality of the riparian habitat. Runoff from newly graded slopes and ditches can carry clay and silt into the stream, where it causes turbidity, which is dangerous to fish and can smother aquatic vegetation and invertebrate life. On the other hand, through erosion, scour, and flooding, rivers and streams can affect the safety and stability of roadway infrastructure.

These aquatic ecologists are conducting a biological inventory of the fish and insects in a stream in Great Smoky Mountains National Park in Tennessee and North Carolina. *Photo: Anita Goetz, U.S. Fish and Wildlife Service, and Kevin Moody, FHWA.*

"Where roads intersect rivers, they almost always interfere with the river's and the ecosystem's integrity," says Kevin Moody, an ecologist with the Federal Highway Administration's (FHWA) Resource Center in Atlanta. "Rivers adjust to road-related and other perturbations in ways that can threaten infrastructure like roads and other property."

Understanding how stream ecosystems work can help transportation professionals make better decisions during planning, construction, and maintenance to protect these sensitive environments—and ensure the long-term stability of the roadways and bridges themselves.

The National Highway Institute (NHI) offers a variety of courses designed to address the transportation industry's growing focus on reducing the environmental impacts of roadways. For example, NHI's course Managing Road Impacts on Stream Ecosystems: An Interdisciplinary Approach (FHWA-NHI-142048) examines how roadways affect stream ecosystems and underscores environmentally sound countermeasures that can minimize those impacts.

Mitigating Effects, Practical Solutions

Unlike roads and bridges, rivers and streams are nonstationary entities and can move in four dimensions: One is temporal (flow volumes change seasonally and due to weather events), and three are spatial (lateral or cross section, longitudinal or up- and downstream, and elevation or depth). Streams continuously change to flow more efficiently, which means they engage the entire landscape from all directions. Because streams interact with their environment from these four dimensions, the introduction of permanent, unyielding structures such as roads can result in undesirable effects on the ecosystem.

Because of technological developments, transportation professionals now are able to monitor the effects of roads on nearby stream ecosystems using electronic sensors and biological surveys. "The continued improvements in technology and computational capacity have enhanced our ability to understand the cause-and-effect relationships between roads and streams, and make our predictions much more robust than just 10–15 years ago," Moody says.

Managing Road Impacts on Stream Ecosystems introduces the basic concepts. The 3-day course highlights the physical and ecological characteristics of stream environments, examines the impacts of roadways, and discusses ways practitioners can avoid and limit adverse effects. For example, the course includes a strong focus on environmentally sound ways to guide a stream's flow and velocity, such as using root wads, stone weirs, or log cribs. These options, unlike traditional approaches such as concrete aprons, are more likely to maintain or restore the integrity and natural infrastructure of a stream.

About the Course

The course targets staff at FHWA, State departments of transportation, environmental resource agencies, and consultants involved in the design, construction, operation, and maintenance of roadway facilities. The training is intended to benefit engineers and environmental specialists involved in highway design, planning, and maintenance.

Through case examples and group discussions, participants have the opportunity to use critical thinking to develop solutions and identify preventive measures. The case studies feature lessons learned from around the country and include examples of both successful and failed attempts.

The most important thing that participants will take away from the course, according to Moody, is that all decisions regarding road and stream interaction must be context sensitive and made on a case-by-case basis. "There is no one-size-fits-all solution to managing road impacts on streams," Moody says.

For more information, visit NHI's Web site at www.nhi.fhwa.dot.gov. To schedule a session, contact the NHI Scheduler at nhitraining@dot.gov or 703-235-0534.

Rachel Grant is a contractor for NHI.

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:

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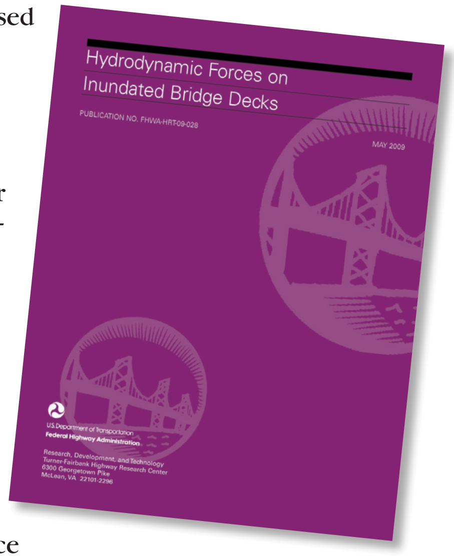
Fax: 814–239–2156
E-mail: report.center@dot.gov

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.

Hydrodynamic Forces on Inundated Bridge Decks
Publication No. FHWA-HRT-09-028

When a bridge crossing a waterway is partially or entirely submerged during a flood event, its deck could be subjected to significant hydrodynamic loading. Accounting for the hydrodynamic forces that might be exerted on an inundated bridge deck is critical in the design of bridges. Specifically, the drag and lift forces, the moments acting on the bridge deck (unevenly distributed forces that can cause the bridge to overturn) under various levels of inundation, and a range of flow conditions influence the design and construction of bridges.

This report documents reduced-scale experiments and computer modeling that explore the forces acting on bridges. Analysts used three bridge deck prototypes for the experiments: a typical six-girder highway bridge deck, a three-girder deck, and a streamlined deck designed to better withstand hydraulic forces. The researchers measured the forces on each bridge deck shape in the laboratory with an ultraprecise force balance under a range of scenarios.



Analysts performed computational fluid dynamics (CFD) simulation modeling using two commercial software packages. They tested a range of model options from two-dimensional to three-dimensional. The analysts generated design equations for each of the bridge types and force coefficients.

According to the report, the CFD simulations seem promising as a method to test bridge designs, but more research is needed before complex designs can be tested wholly in the CFD realm. However, the design charts from the experimental results should be a valuable tool for bridge designers in a wide range of design applications.

The report is available at www.tfhrc.gov/structur/pubs/09028/index.htm. Printed copies are available from NTIS under order number PB2009-111423.

Corrosion Resistant Alloys for Reinforced Concrete
Publication No. FHWA-HRT-09-020

For decades, transportation agencies have recognized that deterioration of concrete bridges due to corrosion of reinforcing steel is a major technical and economic challenge. As one means of addressing the problem, researchers with the Florida Department of Transportation and Florida Atlantic University are looking at corrosion-resistant reinforcements, such as stainless steels.

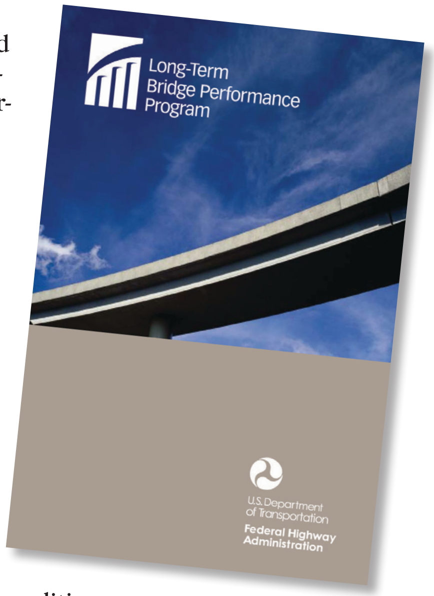
In the first interim report for this project, the researchers presented results from short-term tests and preliminary results from long-term exposure of reinforced concrete slabs. This, the second interim report, provides longer term data and analyses of chloride exposures that involved four types of reinforced concrete specimens, two of which simulate northern bridge decks exposed to deicing salts, while the remaining two simulate marine substructure elements.

Researchers used three concrete mix designs. Specimen types included combinations with a simulated concrete crack, bent top bar, corrosion-resistant upper bars and black steel lower bars, and intentional clad defects such as an exposed carbon steel substrate. The exposure lasted more than 4 years. The researchers ranked the candidate alloys according to performance and analyzed how they might perform in actual concrete structures.

The report is available at www.tfhrc.gov/structur/pubs/09020/index.htm.

Long-Term Bridge Performance Program (Brochure)
Publication No. FHWA-HRT-09-033

In April 2008, FHWA's Office of Infrastructure Research and Development launched the Long-Term Bridge Performance (LTBP) program, a flagship research project with the objective of collecting scientific-quality data on the Nation's highway bridges. FHWA envisions the LTBP as a 20-year or longer examination of highway bridges to improve knowledge of bridge performance and ultimately promote the safety, mobility, longevity, and reliability of the country's highway transportation assets. This brochure details the program's objectives and methodologies.



The LTBP program aims to compile a comprehensive database of quantitative information from a representative sample of bridges nationwide, looking at critical bridge elements and the factors that affect their performance—age, material, design, condition, use, and environment. By taking a holistic approach and analyzing the physical and functional variables that affect bridge performance, the program will provide a more detailed and timely picture of bridge health and better tools for bridge management.

Printed copies of the brochure are available from FHWA's Office of Infrastructure Research and Development by phone at 202–493–3024, fax at 202–493–3442, or e-mail Monique Smith at monique.smith@dot.gov.

Conferences/Special Events Calendar

Date	Conference	Sponsors	Location	Contact
November 8–12, 2009	ACI Fall Convention: Spice Up Your Concrete	American Concrete Institute (ACI)	New Orleans, LA	ACI Event Services 248-848-3795 conventions@concrete.org www.concrete.org/Convention/Fall-Convention/Front.asp
November 16–19, 2009	12th Annual National Tribal Transportation Conference	Tribal Technical Assistance Program, Federal Highway Administration, Bureau of Indian Affairs	Phoenix, AZ	Dottie Fucetola or Ron Hall 800-262-7623 or 970-491-1007 ttap@colostate.edu http://ttap.colostate.edu
November 18–20, 2009	NYS Public Transit Fall Conference	New York Public Transit Association	Albany, NY	Angela Johnston 518-434-9060 info@nytransit.org www.nytransit.org
November 30–December 4, 2009	ACPA 46th Annual Meeting	American Concrete Pavement Association (ACPA)	Orlando, FL	ACPA Meetings & Events 847-966-2272 acpa@acpa.org www.acpa.org
December 9–11, 2009	Conference on Improving the Seismic Performance of Existing Buildings and Other Structures	Applied Technology Council and Structural Engineering Institute of the American Society of Civil Engineers	San Francisco, CA	Vicki Johnson 703-532-3166 vicki@vjmeetings.com www.atc-sei.org
December 13–15, 2009	Transportation Finance Summit	International Bridge, Tunnel and Turnpike Association	Washington, DC	Cheryle Arnold 202-659-4620, ext. 15 carnold@ibtta.org www.ibtta.org
December 13–18, 2009	12th International Conference on Travel Behaviour Research	Transportation Research Board (TRB)	Jaipur, India	Kimberly Fisher 202-334-2968 kfisher@nas.edu www.iatbr2009.org
January 10–14, 2010	TRB 89th Annual Meeting	TRB	Washington, DC	TRB Meetings Department TRBMeetings@nas.edu www.trb.org

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