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September/October 2004

2003 Blackout

I–95 Shutdown

Update on Accessibility

U.S. Department of Transportation

Federal Highway Administration

Public Roads

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

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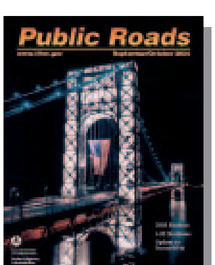

Front cover—When the largest power outage in U.S. history rolled across much of the Northeast from Detroit to New York City on August 14, 2003, the George Washington Bridge, shown here with a huge American flag, continued to operate because it received power from a number of sources. Meanwhile, portions of Michigan, Ohio, Pennsylvania, New Jersey, New York, Connecticut, and Vermont were left in the dark. *Photo: Port Authority of NY and NJ.*

Back cover—In August 2004, FHWA oversaw the application of a test strip of rustic pavement placed on a section of roadway in Rock Creek Park in Washington, DC. The crew smooths the surface prior to compaction on this test strip of aggregate mix and synthetic binder. *Photo: Kevin Connor, FHWA.*

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Guest Editorial

Preparing for the Unexpected

The transportation network is an integral part of American life. It contributes to our national connectivity and prosperity, supporting work and leisure activities and providing for the delivery of essential services during emergencies. The events on September 11, 2001, and those highlighted in this issue of PUBLIC ROADS serve as reminders that the Nation needs to be ready for unexpected emergencies.

The very nature of emergencies is that they are unpredictable and chaotic, harboring the possibility of injuries, property damage, and sometimes death. Panic can erupt. Depending on the circumstances, fast thinking and flexibility are necessary. But even more critical is the development and testing of response plans that help guide decisions in a host of emergency situations.

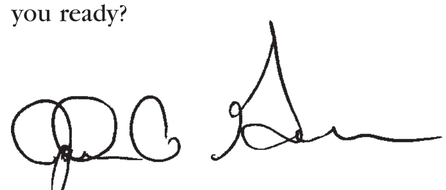
In the past year, the transportation community has responded to several large-scale emergencies related to weather, power, seismic, and chemical events. Most agencies are prepared for brief road closures and small-scale emergencies, but how equipped is your agency to handle a major disaster? How would you handle a chemical explosion that shuts down a main artery during rush hour? What contingencies do you have if a power outage closes down your traffic control devices, transit system, or other key infrastructure?

Planning and preparing for a problem or emergency before it happens potentially makes response quicker and smoother.

The 2003 blackout that affected seven States underscores the importance of emergency planning when the transportation grid is dark. The cities affected by the blackout share their experiences and how they handled the crisis in "Learning from the 2003 Blackout" on page 22. Another article, "I-95 Shutdown—Coordinating Transportation and Emergency Response" on page 42, highlights Maryland's response to a tanker truck explosion on I-95 just before rush hour on January 13, 2004. The authors discuss agency response, command structure, alternate routing, and the efforts made to keep traffic moving in this major north-south interstate corridor.

As States expand their emergency response plans to address unexpected events, the challenges will be numerous: coordinating multiple-agency response with the possibility of involving new players; setting up a command structure; considering how to respond if the event is deemed a terrorist attack; and exercising flexibility in dealing with atypical situations. Some elements to consider include the need to handle large evacuations while providing access for emergency response units and supplies, providing a means to meet internal and public information needs when the communication infrastructure is damaged, coordinating with a military response in the appropriate situation, and responding without key resources like electrical power.

The transportation community may not be able to prepare for every contingency, but we need to have a basic plan, conduct exercises to test and enhance that plan, and then begin to address some of the extreme conditions discussed in these articles. Are you ready?



John A. Gerner
Program Manager for
Transportation Security
Office of the Administrator
Federal Highway Administration

TAKING THE HIGH

What happens when a transportation project is scheduled to move a road closer to a historic farmstead or a planned interstate route cuts through the cultural heart of a major city? Transportation planners across the country frequently grapple with conflicts between transportation needs and the desire to preserve historic and cultural resources. When project planning fails to identify stakeholders in such properties and to take their views into consideration, projects can run into costly schedule delays sparked by disagreement among stakeholders.

Generally, historic properties are defined as those that are at least 50 years old and possess historic, archaeological, engineering, or architectural significance. Any type of building, structure, historic district, or site that is listed or eligible for listing in the National Register of Historic Places—the official national list of cultural resources worthy of preservation—is considered a historic property. Examples include a late 19th-century school, a neighborhood of early 20th-century bungalows, a park developed by the New Deal's Civilian Conservation Corps, a gas station constructed when an early highway was built, or a downtown commercial center.

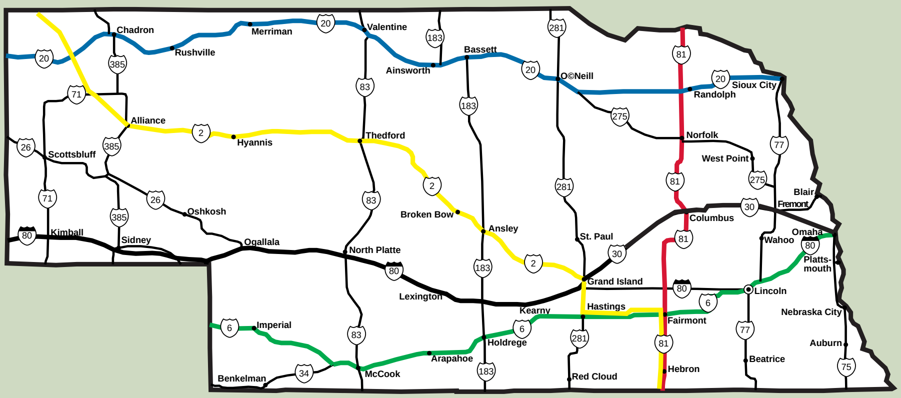
Section 106 of the National Historic Preservation Act of 1966 requires that the Federal Highway Administration (FHWA), often working through State departments of transportation (DOTs), take into account the effects of road projects on historic properties. Two State agencies—the Nebraska Department of Roads (NDOR) and the Florida Department of Transportation (FDOT)—are leading the way by adopting proactive approaches toward preserving and revitalizing sites of historic significance. Through thoughtful planning, interagency cooperation, context-sensitive design solutions, and strong partnerships with FHWA, both States have taken the high road when it comes to preserving history.

(Above) This brick section of the Lincoln Highway, west of Omaha in Douglas County, NE, is listed in the National Register of Historic Places. *Photo: Nebraska Department of Roads/ Nebraska State Historic Preservation Office.*

ROAD

Two States share different approaches to protecting historic and cultural resources along America's highways.

by Christina Slattery and Steve Jacobitz



This map of Nebraska shows the major historic highways that were the focus of the recent study. (Red route = Meridian Highway, Green route = Detroit-Lincoln-Denver Highway, Black route = Lincoln Highway, Yellow route = Potash Highway, Blue route = U.S. Highway 20). *Source: Nebraska Department of Roads/Nebraska State Historic Preservation Office.*

Nebraska's Historic Highway Survey

In 2001, the Nebraska State Historic Preservation Office (SHPO) initiated an unprecedented, comprehensive statewide survey of historic properties along five of the State's earliest automobile routes. The goal of the year-long study, completed in cooperation with NDOR, was to solve a reoccurring problem facing both agencies: a lack of knowledge of where historic roads and related resources are located. This shortcoming could hinder the successful and timely identification and evaluation of historic properties, as required by Section 106 regulations, and result in project delays.

NDOR and SHPO, which is a division of the Nebraska State Historical Society, both have roles in planning highway projects and managing cultural resources. During a review of proposed projects, SHPO began investigating the historic significance of road segments and related properties that might be affected by future highway improvements. Rather than face repeated conflicts over the question of historic significance, the two agencies partnered to conduct a survey of historic roads statewide. "The survey offered us a great opportunity to team with NDOR on a project that will make our respective agencies' Section 106 responsibilities easier on future projects," says SHPO Resource Planning Program Associate Bill Callahan.

The project was funded by SHPO under its annual Historic Preservation Fund Grant from the U.S. Department of the Interior's National Park Service, as well as matching funds from NDOR. The agencies collaborated to develop the work scope, participate in progress meetings, and review the survey results. "The survey is a tremendous addition to our understanding of how vehicular culture and the evolution of highway construction have shaped our State's built environment," Callahan says.

NDOR and SHPO selected historical consultants to study the historic contexts for the following roads: Interstate 80, Lincoln Highway, Detroit-Lincoln-Denver Highway, Meridian Highway, Potash Highway, and U.S. Highway 20. All represent major highways of regional or national scope and were developed in the early- to mid-20th century to serve America's automobile travelers. The

Nebraska Department of Roads/Nebraska State Historic Preservation Office

Thousands of historic properties, such as the Belvidere Filling Station along the Meridian Highway, were identified and evaluated during the survey.

Nebraska's Survey Methodology

To gain an understanding of the evolution of its historic highways and related resources, the Nebraska State Historical Society and the Nebraska Department of Roads prepared a statewide historic context (a document tracing the historic significance of properties), beginning with the development of formalized road construction at the turn of the century and concluding with the completion of Interstate 80 in 1974. The historic context document includes the following topics: Nebraska's major road development efforts from the turn of the 20th century through post-World War II, State and Federal road legislation and funding, road signage, and statewide trends in road improvements and pavement.

Historic contexts also were prepared for five individual roads, which are representative of well-known, early automobile routes established between approximately 1911 and 1925 (Lincoln Highway, Detroit-Lincoln-Denver Highway, Meridian Highway, Potash Highway, and U.S. Highway 20). Research efforts relied heavily on materials in the collections of both agencies, including annual reports, project log records, historic maps, automobile guidebooks, period newspaper articles, county and local histories, and historic photographs.

For each of the five historic highways, the consultant identified multiple alignments spanning from the roads' earliest alignments through subsequent changes dating to approximately 1940. The project budget and timeframe limited the number of road segments that could be observed in the field, so a peak period for development and use of each road was identified for evaluation. The consultant conducted an architectural survey along the identified alignments to identify historic road segments, bridges, and road-related property types that served the traveling public, such as gas stations and motels. Properties were surveyed and mapped for documentation. In addition, photographs were taken of structures that were constructed before 1960 and structures that continue to function as road-related resources, such as gas stations.

Documented properties generally were located within 0.4 kilometer (0.25 mile) from the right-of-way. In total, approximately 5,600 kilometers (3,500 miles) were surveyed, and more than 900 road-related property types were documented.

consultants also conducted a survey of the historical and architectural features along the highways, with the exception of Interstate 80.

The consultants drove thousands of miles to identify the historic routes and inventory the different types of road-related resources, such as buildings, objects, and structures. The survey focused on property types specifically associated with the historic transportation routes frequented by automobile tourists, including sections of early roads and waysides, bridges, gas stations, cabin courts and motels, diners and drive-in restaurants, and vintage tourist attractions. "Historic roadside resources, including gas stations and cabin courts, are quickly disappearing from our landscape," says Deputy State Historic Preservation Officer Bob Puschendorf from the Nebraska State Historical Society.

According to Puschendorf, developing a historic context has led to a better understanding of the history of road development and construction in Nebraska. Although intact examples of historic gas stations are increasingly rare, the survey found that historically this was a common type of property along the roadways studied. "These resources," explains Puschendorf, "tell a significant story about the development of roads, road-related services, and tourism across the State."

Cindy Veys, NDOR's environmental section manager, indicates that NDOR and SHPO are using the survey results for future project planning, NEPA development compliance activities, and outreach efforts to educate the public about the significance of the State's historic properties. She adds that her agency is benefiting from the project's products—historic contexts, the survey report, and Multiple Property Document Forms for the National Register—all of which "facilitate [NDOR's] decisions regarding the eligibility of roadways and road-related resources [for listing in the National Register] in cases of Section 106 compliance." As a result, NDOR has an early understanding of what historic properties may be affected, which in turn provides greater opportunities to avoid potential conflicts and streamline the NEPA process.

The Advantages of a Holistic Approach

The survey offers long-term benefits as well. NDOR will save time and money in project development because the historic properties already have been identified prior to road improvements or bridge replacement projects. And the development of a statewide historic context makes the evaluation of resources easier, faster, and more objective than ever before.

With the comprehensive study, NDOR and SHPO can evaluate small sections of roads and determine the eligibility of particular road segments for the National Register. The results can be applied on a project-by-project basis, enabling the agencies to come to agreements quickly.

Nebraska Department of Roads/Nebraska State Historic Preservation Office

This 7.3-kilometer (4.5-mile) stretch of the Meridian Highway in Pierce County retains its original alignment, design, and historic character—including this small metal truss bridge—and has been listed in the National Register of Historic Places.

This view through the archway of one of the historic structures shows I–4 crossing through Ybor City, FL.

The plan is to house the data in a geographical information system layer that can be updated as needed.

The survey project was completed in 2002, and the results already are helping shape new transportation projects, according to NDOR Highway Environmental Program Manager Len Sand. NDOR and SHPO are distributing the final report to local groups to support their efforts to preserve historic roadside properties through the Nebraska Transportation Enhancement Program, Nebraska's Scenic Byways, and the Nebraska Lied Main Street Program. "We've received enthusiastic responses on the final survey report from both NDOR personnel and the public," says Sand. "We're already printing additional copies."

A book intended to expand the public's knowledge and appreciation of Nebraska's highways and road-related historic properties also may be forthcoming from the Nebraska State Historical Society. In addition, NDOR recently provided funding to SHPO for a pilot project to enter the survey results into its geographic information system (GIS). After mapping the surveyed properties, NDOR and SHPO will be able to use the GIS to identify the locations of potential historic sites quickly when planning projects.

To learn more about the survey or Nebraska's historic highways, access the final report, *Nebraska Historic Highway Survey*, on the Web at www.dor.state.ne.us/docs/NE-Hist-hwy-surv.pdf and www.nebraskahistory.org/histpres/historic_highway_book-web.pdf. The report provides a history of road development in Nebraska and highlights the results from the survey, including significant historic properties.

A Highway Splits a City

A historic property across the country shows how road improvements and economic prosperity can coincide. Forty years ago, the news of Interstate 4 coming through the heart of Tampa, FL, was a harbinger of economic revitalization. The new Federal-aid highway promised to boost commerce, expand tourism, and speed local commuters to and from work. The roadway also offered the city a means to spur urban renewal in areas dotted with crumbling factories and decaying homes.

But for the residents of the old Ybor City neighborhood just east of downtown Tampa, I–4 held a somewhat bleaker promise. For almost half a century, Tampa's Ybor City section was the focal point of the U.S. cigar industry. But by the 1950s, mass-produced cigarettes and a steep decline in the demand for hand-rolled cigars left the community with only a faint economic heartbeat. Still, Ybor City hosted a vibrant nightlife and was home to a Hispanic community that is proud of its cultural traditions and historic accomplishments.

When I–4 cut an east-west swath through the center of the Ybor City neighborhood, it had two unfortunate side effects. First, many historic structures were sacrificed to the shared interests of acquiring right-of-ways and removing urban decay. Second, the highway had the unexpected impact of dividing the Ybor community both physically and socially into a prospering southern section and a declining northern section.

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Loaded on a truck is one of five "casitas" (small houses) donated to the Ybor City Museum State Park.

While homes and commercial buildings north of I–4 lost value and fell into serious disrepair, the Ybor neighborhood south of the highway had an almost miraculous renaissance. In 1974, thanks to the efforts of involved Tampa residents, Ybor City was placed on the National Register of Historic Places. The downtown area, including 948 historic structures, was designated a National Historic Landmark District in 1991. South of I–4, Ybor took on a new luster with restored brick streets, signature five-globe iron street lamps, trendy shops and clubs, a distinctive urban shopping complex, and the new Ybor City Museum State Park, featuring not just displays, but historic buildings to help tell the story of Ybor City's past.

The Tampa Interstate Study

By the early 1990s, FDOT realized that the interstate corridors in Tampa needed substantial upgrading. One outcome was the Tampa Interstate Study (TIS), which addressed the long-term needs of I–4 and I–275 by proposing a new crosstown connector linking I–4 with the Leroy Selmon Crosstown Expressway. The new connector would help divert truck traffic from Ybor's streets. With a projected cost of nearly $1.1 billion, the TIS connector qualified as one of the Nation's current transportation megaprojects.

In the 5.1-kilometer (3.2-mile) stretch of I–4 crossing through Ybor City, TIS called for doubling the number of lanes by adding eight new collector/distributor lanes outside the present roadway. When construction of this segment is completed in 2008, the old four-lane roadway will be removed. Possible future uses might include express lanes, HOV lanes, or a rail corridor. Although the plan would bring needed advancements to the transportation infrastructure, Ybor City once again faced the prospect of losing more historic structures to highway right-of-way needs. In addition, the plan had the potential to create an even wider physical separation between the northern and southern sections of the community.

TIS staff at FDOT's District Seven Headquarters in Tampa and the FHWA Florida Division noted early-on the plight of Ybor City and sought to correct the problems that I–4 had created four decades earlier. This time, Ybor's historical significance and the needs of its residents would be in the forefront as highway improvement plans were developed.

Cigar Capital of the World

Ybor City was born as a 16-hectare (40-acre) tract of scrubland east of Tampa that was purchased by cigar manufacturer Vicente Martinez Ybor in 1885. Ybor, a Spanish-born Cuban living in political exile, thought the Tampa area was ideal for cigar manu-

The I–4 Historic Relocation and Rehabilitation Project took great care to preserve structures, like this former boarding house, that represent the diversity, of architectural styles present in Ybor City.

Moving fragile wood-frame houses like this one with significant deterioration was a major challenge. The complex task required skill, knowledge of the route, and great care.

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facturing. Land was cheap; Tampa's seaport and recently arrived railroad provided easy commercial transportation; and the hot, humid climate was perfect for storing tobacco. A year later, when his Key West cigar factory burned, Ybor built a factory on the new tract, surrounding it with affordable housing to coax skilled cigar makers—called *tabaqueros*—from Key West.

"Mr. Ybor's City," as it was known, soon attracted other cigar manufacturers from Key West and as far away as New York and Cuba. In 1887, the Tampa Board of Trade made the area Tampa's fourth ward. By the turn of the 19th century, Ybor City eclipsed Havana, Cuba, as a source of fine, hand-rolled cigars, laying claim to the title of "Cigar Capital of the World."

Restoring the Past

The challenge facing the TIS project was not a simple one. Improvements to I–4 in the Ybor City area could adversely impact historic resources. Even with careful routing to avoid historic structures whenever possible, many would end up in the right-of-way corridor.

When the FHWA Florida Division, FDOT, the Florida State Historic Preservation Officer, the Advisory Council on Historic Preservation, and the city of Tampa signed a preliminary memorandum of understanding in 1996, the document called for a number of innovative steps to mitigate the potential environmental impact. The steps included following an extensive set of urban design guidelines developed by FDOT and thoroughly documenting all affected historic structures. In addition, 35 historically significant structures built between 1895 and 1930 were to be relocated, rehabilitated, and turned over to the city of Tampa for sale to qualified buyers. Of the relocated structures, 26 would be in the Ybor City neighborhood north of I–4, and 5 were to be donated to the Ybor City Museum State Park.

Rick Adair, environmental administrator for FDOT's District Seven, was involved at the beginning of the project when the environmental scope seemed truly daunting. "The environmental impact statement took 8 years," he says, "primarily because of the extent of historic resource involvement that was required." Covering 40 kilometers (25 miles) of improvements in urban areas, TIS involved a major impact. "The documentation requirements brought many people into the process," Adair adds.

According to District Seven Secretary Ken Hartmann, in 1997, TIS "resulted in the largest environmental document of its kind in the country at the time."

A high level of community involvement has distinguished this project from the outset. A group of local citizens, acting through a Cultural Resource Committee, has been intimately involved in the selection process and the rehabilitation plans for each of the relocated structures. "The TIS [committee] is unique," says Adair, "[because] usually participation in these groups will dwindle over time, but not this one."

Laying the Groundwork

In 1999, FHWA funded $8 million for the I–4 Historic Relocation and Rehabilitation Project. Work had to begin quickly because many of the historic homes were in an extreme state of disrepair. Vandalism and arson also posed a constant threat. Early right-of-way acquisition started during the project's design phase to help prevent further loss. "Relocation property was only purchased from willing sellers," says Interstate Historic Resources Coordinator Elaine Illes, who has been close to the project since its earliest days. "Fortunately, the city of Tampa owned many properties along the [right-of-way], and city involvement added to the 'partnership' of the project."

At the same time, FDOT launched the complex process of finding a new lot for each of the designated structures. The criteria included providing a setting appropriate for each structure and its historical importance, as well as practical considerations, such as the distance of a move and availability of affordable, preferably vacant, lots.

"We called it the *puzzle*," says Illes, describing the process that helped determine which structures to relocate. "First," she explains, "we looked at examples of different architectural styles, historic fabric, and the ability of the building to make the move. Then we had to determine the best placement, whether each

Built in 1932 of yellow Italian brick, this Mediterranean Revival-style home awaits restoration (top). Masons dismantled the home's distinctive fence and rebuilt it brick-by-brick at the new site (bottom).

Parsons, Brinckerhoff, Quade & Douglas, Inc.

structure would fit on the lot chosen, and if we could meet all of the code requirements."

Illes continues, "We tried to keep things in context. As much as possible, we matched neighboring houses and retained the original orientation. Unfortunately, when a house would burn because of vandalism or neglect, we would have to go through the process all over again."

In addition to lot selection, just moving the often-fragile historic structures, which frequently were simple wood-frame houses with significant deterioration, was a major challenge. FDOT District Seven Right-of-Way Administrator Bill Scott served as project manager overseeing the job of moving and restoring the historic houses. "This was strange for me," he says, noting that his usual position involves demolition—not reconstruction—along the right-of-way.

"Originally, we thought we would put the relocation project out for bid on a districtwide basis," Scott explains. "But we didn't yet own all of the structures and couldn't disclose their addresses, so the only specifications we could provide were basically the square footage." Since moving a property is so dependent on such complexities, as well as the specific distance and route to the new location, contractors were reluctant to bid on that basis. "Realizing bid cost would be much higher with all the unknowns," Scott says, "we decided to bid the individual moves as we obtained the properties."

In the end, the relocation projects took almost 2 years but were accomplished without major incident. According to Scott, "There was damage to some of the more deteriorated structures—mostly to a few of the less stable porches—as you might expect, but nothing we didn't anticipate."

Better Than New

Key to the success of the project in Ybor City is rehabilitating the relocated homes to maintain their historic appearance while ensuring they remain attractive to today's home buyers. Although historical preservation generally focuses on the exterior of structures, Scott describes the Ybor City effort as trying "to preserve as much of the historic interior as possible while putting in a [number] of improvements to be sure the houses were marketable once we turned them over to the city of Tampa to be resold."

FDOT also paid careful attention to the setting for the homes. "Aesthetically complementing the community was an important design consideration," says Illes, citing the incorporation of brick knee walls, Medjool date palm trees, a four-tiered lighted fountain, and vintage five-globe street lights that are a hallmark of Ybor City. "It is all aimed at reuniting a community," she says.

Even though rehabilitation work is still underway, the positive results of the project are already evident. According to FDOT District Seven Secretary Hartmann, "Once people saw the finished product with the first few homes, they were committing to buy before houses were rehabilitated." At the time of this writing, all of the available restored, fixed-

Photos: Parsons, Brinckerhoff, Quade & Douglas, Inc.

From eyesore to landmark home, the transformation was extreme, as can be seen through these before (left) and after (right) views of two typical structures.

price homes are sold or under contract, and there is a waiting list for the remaining structures. "Interest in some of the homes was so high that a lottery was required to select from the many bidders," he adds.

Perhaps of greater significance, many homeowners in the area have begun their own rehabilitation projects as local property values climb with the success of the I–4 historic mitigation effort. Echoing the thoughts of many, FDOT's Scott acknowledges, "I was skeptical at first, but now I see it happening."

"It's exciting to take an active leadership position with a project such as this," says FDOT's Hartmann, reflecting on the agency's positive experience with the successful restoration effort. "Major highway improvements often are accused of destroying communities," he admits, "but in this instance, we're clearly enhancing one."

For information on the Ybor City project, visit www.mpivideo.com/videos/historic.html to view "Partners in Preservation," an 8-minute online video on the project. Visit http://mytbi.com/urs/content/design/I275-I4-Downtown to see before and after photos of the I–275/I–4 interchange and Ybor City.

Taking the High Road

The historic preservation projects in both Nebraska and Florida have proven successful beyond expectations. Each demonstrates the critical importance of embracing history, preserving the reflections of past and present communities along the Nation's roadways, and—in some cases—healing the wounds to which those very roads contributed.

Although each project highlights a different approach, both share a common theme: Section 106 regulations represent an opportunity to incorporate historic preservation into the planning of future transportation infrastructure. Nebraska's catalog of historic resources along its roadways will help planners, road builders, and historians make more informed decisions that affect significant roadside features. In Florida, FDOT and FHWA demonstrated the value of teaming with concerned citizens to preserve historic structures and help restore the fabric of a community that was torn apart by an interstate highway years before.

Roads can be much more than gravel, concrete, or asphalt, particularly when they symbolize a pathway through the Nation's rich and varied history. The initiatives undertaken by Nebraska and Florida will benefit future generations long after the dust of highway construction has settled.

Christina Slattery is a senior architectural historian at Mead & Hunt, Inc., a consulting engineering/architecture firm. She served as project manager for the *Nebraska Historic Highway Survey*. She holds a master's of science degree in historic preservation, and her consulting experience includes conducting historic surveys, preparing nominations for the National Register, developing historic contexts, and facilitating Section 106 compliance activities for projects throughout the country.

Steve Jacobitz is a marketing and communications specialist based in the FHWA Florida Division in Tallahassee. Jacobitz joined FHWA in 2003, after serving as a communications director and a marketing projects director in the financial services industry.

THE SPACE

(Above) This computer-enhanced photograph shows the future Washington Bridge 200 relocation adjacent to Washington Bridge 700. The narrow bridge to the right of the main spans is a portion of old Bridge 200, converted into a park with bicycle and pedestrian lanes. In the inset photo, Washington Bridge 700 and Washington Bridge 200 are separated by a 13.7-meter (45-foot) gap. RIDOT will use the space between the spans to construct a replacement for Bridge 200. *Photos: RIDOT and Pineapple Studios, Inc.*

BETWEEN

by Dana Alexander Nolfe

An innovative infill project helped the Rhode Island DOT replace an aging bridge while preserving part of the original structure as a bike and pedestrian route.

When planned repairs to a crucial bridge in Providence, RI, revealed the need to replace the aging structure, the Rhode Island Department of Transportation (RIDOT) faced a complex challenge—the heavily traveled bridge is historically important and hemmed in by existing communities.

Washington Bridge 200 connects Rhode Island to Cape Cod and other parts of Massachusetts. The busy Interstate 195 (I–195) thoroughfare carries 90,000 cars per day eastbound over the Seekonk River. Westbound traffic crosses the river on an adjacent structure, Washington Bridge 700.

Built in 1930, Washington Bridge 200 is one of only three large, open-spandrel bridges in Rhode Island. When RIDOT began planning repairs, previous experience rehabilitating one of the other open-spandrel bridges—the Ashton Viaduct Bridge 275—prompted the department to conduct a thorough investigation of the condition of the concrete. "The lessons we learned at the Ashton Viaduct, where reconstruction was completed in 2000, showed us how to proceed on the Washington Bridge," says RIDOT Director James R. Capaldi, P.E., who was chief engineer on the Ashton Viaduct work.

Although preconstruction testing on Ashton Viaduct indicated that the concrete was reasonably sound, the extent of the necessary repairs greatly exceeded the engineers' original expectations, and the bridge ultimately needed to close for major repairs.

"Once we got into Washington Bridge, we realized we should do additional tests," says RIDOT Chief Engineer Edmund T. Parker, Jr., P.E. "Early in the process we understood that the concrete was not what we expected it to be." Upon close investigation, RIDOT inspectors discovered that the Washington Bridge was plagued with a patchwork of good and bad concrete intermingled. What should have been a repair job was turning into a much larger replacement project.

Adding to the challenge, the historic bridge is located in an area where the right-of-way acquisitions necessary to build a new structure would be costly. And the project needed to be timed carefully to open in the summer of 2008, when a new 1.6-kilometer (1-mile) segment of the I–195 Relocation Project will open and connect to the Washington Bridge.

The solution? RIDOT developed a plan to build a new five-lane bridge that fits snuggly within the 13.7-meter (45-foot) gap between the existing east and westbound structures. A win-win solution, the project would not affect daily traffic or encroach on the rights-of-way of neighboring communities—and it would preserve part of the historic bridge as a scenic bicycle and pedestrian route. Here is how RIDOT did it.

A Decorated History

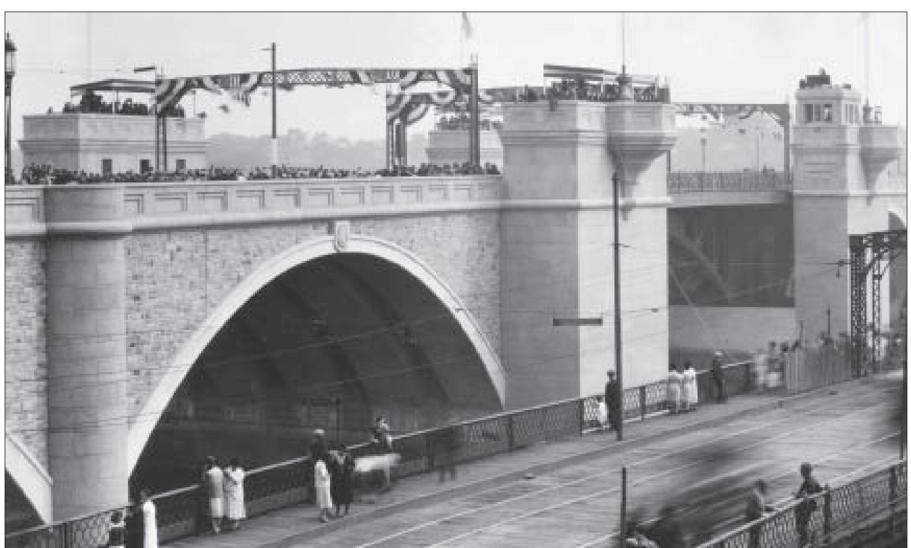
More than 70 years old, Washington Bridge 200 is considered to be Rhode Island's premiere historic bridge. The current structure replaced an outmoded steel-truss swing-span bridge built in 1885, which carried a streetcar line on an 8.2-meter (27-foot)-wide roadway.

When former Rhode Island Governor Norman S. Case formally inspected and opened Washington Bridge on September 25, 1930, the bridge provided the first direct highway connection between Rhode Island's two leading cities, Providence and Newport. The structure exemplified the City Beautiful movement of the late 19th and early 20th centuries and the Classical Revival style of architecture.

In November 1930, the American Society of Civil Engineers' *Civil Engineering* magazine said the Washington Bridge was "a product of a combination of the highest type of engineering and architectural skill, and will long stand as an object of utility and beauty of which the people of Rhode Island may well be proud."

The open-spandrel, reinforced concrete arch bridge was a popular style for early 20th century multiple-span highways bridges. The Washington Bridge stretched 549 meters (1,800 feet) in length, and at 25.9 meters (85 feet) in width, the bridge was exceptionally wide for its time. Rather than a massive, concrete-filled

RIDOT/Hussey Historic Photographic Collection



Crowds gathered on the Washington Bridge to celebrate its official dedication on September 25, 1930. The older, steel-truss swing bridge, built in 1885 over the Seekonk River, is visible in the foreground.

RIDOT/Hussey Historic Photographic Collection

The cast bronze flagpole base on the northeast tower reflected the Classical Revival style and demonstrated the level of detail that went into the bridge's original design. The photo was taken on September 23, 1930.

structure or solid spandrel walls, the bridge incorporated 6 separate arch ribs, 12 arch spans, and 1,512 vertical columns supporting the roadway deck. At the time, this method was more cost effective because it used less concrete and took advantage of local labor and materials.

In 1968, the State built Washington Bridge 700 directly north of Washington Bridge 200 to carry westbound traffic. Viewed from the side, the newer bridge echoes its elder's classic arched design and will remain unaffected by the work, as it was rehabilitated from 1995 to 1997. Preserving the historic shape and character of the eastbound bridge, therefore, were important goals in the replacement project.

Exploring the Options

After 2 years of intensive maintenance to keep Washington Bridge 200 in service, work began in earnest in 2003 to start the replacement process for the eastbound span. RIDOT anticipated that the rehabilitation would cost $15 to $20 million but ended up facing an $80- to $100-million project.

Building a new bridge south of the existing one would have created a costly right-of-way nightmare. Acquiring the right-of-way from a hotel on the west approach in Providence, for example, would have cost an estimated $40 to $50 million, and an entire neighborhood on the east approach in East Providence would have put the price out of the ballpark.

Closing the bridge for construction was not an option. "Too many people depend on it to get to work every day," Capaldi says. "Closing it would paralyze our State."

RIDOT needed to devise an alternative strategy. "All of a sudden, we had all these problems with the needs of replacing the bridge: the interstate, traffic, [and] historic issues," says RIDOT Design Project Manager Robert J. Pavia, P.E. "There was no room. Where do you go—left or right to replace the bridge? Then a solution resolved all those questions and turned adversity into opportunity."

With nowhere else to go, the gap between the two bridges became the focus of the design solution. RIDOT decided to build the new eastbound Washington Bridge within the 13.7 meter (45-foot) gap between the two existing structures. As the new bridge is installed adjacent to the Bridge 700, portions of the old Bridge 200 will be removed—all while maintaining four lanes of traffic in the eastbound direction.

"We had to look at an option that allowed us to build a new bridge while maintaining the existing travel lanes," says Richard G. Fondi, RIDOT administrator of the construction management group. "We could narrow them down and shift them, but we couldn't close them. The engineering decision was to start between the bridges and expand from there."

Down the Middle

By working construction from north to south, RIDOT planned to disassemble the bridge in phases. Each of the bridge's arch rings will be removed individually. Four 3.58-meter (11.75-foot) travel lanes temporarily will shift to the south side of the bridge. Prior to construction, the lanes were the standard 3.66-meter (12-foot) width.

RIDOT then will demolish one arch ring—4.57 meters (15 feet) of

RIDOT/Hussey Historic Photographic Collection

Taken on February 28, 1930, this photo shows the historic Washington Bridge 200 under construction (looking west).

C. Aube, RIDOT

Working in the gap between the two bridges, workers use a 108.9-metric ton (120-ton) vibrator to install the 2.1-meter (7-foot) diameter permanent casings for the new bridge.

the bridge width—making the gap grow between the two bridges to 19.8 meters (65 feet), allowing the next phase of construction to occur. Two-thirds of the new bridge will be built in this gap. Another 9.1 meters (30 feet) of the old bridge then will be demolished, and the new bridge completed.

"RIDOT plans to demolish the northernmost arch ring for the full length of the bridge first," says Pavia, whose job is to keep the project moving between engineering and construction. "Bracing will be installed between the piers, with tiebacks put on the arches. We will then sawcut the concrete deck between the two adjacent rings, structurally isolating the northernmost arch ring. Demolition of the concrete deck and columns can then occur, followed by the arch keystone. Finally the cantilevered portions and tiebacks can be removed."

According to Providence Managing Director of Transportation Paul M. Jordan, P.E., of design consultant Vanasse Hangen Brustlin, Inc., "One of the challenges of the design was that the new structure will rest partially on an existing concrete footing–timber pile foundation, as well as partially on new drilled shafts. [We] ensured that the existing timber piles would not be overstressed under static or seismic loads through flexible design of new drilled shafts and the use of isolation bearings."

A new pier bent with a spread footing will be constructed on the existing piers at the spring line of the arches and on the newly drilled shafts.

The first phase of this construction is building one column on a drilled shaft and a partial footing and one column on an existing foundation, followed by construction of a partial pier. Then the contractor will erect the steel superstructure, pour the concrete deck, and shift four lanes of traffic from the south side of the old bridge to the north portion of the new bridge. In the second phase, the contractor will complete the pier bent on an existing foundation using one more column, thus completing the superstructure of the new bridge.

"As a result of this work plan, we have had almost no traffic impacts," says Kazem Farhoumand, RIDOT's chief design engineer. "Most people who travel this bridge don't see any backups or any tieups as a result of our construction thus far."

A Park Like No Other

To save time, reduce costs, protect the environment, and preserve a portion of the historically significant bridge, RIDOT maintained a goal throughout the design process to reuse as much of the original structure as possible. Preserving part of the old bridge as a bicycle and

C. Aube, RIDOT

C. Aube, RIDOT

(Left) RIDOT Resident Engineer Mike Studley overlooks the 2.1-meter (7-foot)-diameter drilled shafts being installed between the two existing bridges.
(Right) A certified weld inspector prepares to test a splice weld on a drilled shaft casing.

C. Aube, RIDOT

This westbound view of Washington Bridge shows cranes at work installing drilled shafts in the 13.7-meter (45-foot) gap between the two existing bridges.

pedestrian path was a key element in this strategy.

"The actual bike path that we had on the old bridge was narrow and really not functional other than for just a bike or two going by at a time," says Fondi. "The idea then developed to retain the southern two arch rings, thus preserving the southern stone facade of the Washington Bridge and building a park. It just seemed better to preserve [what] we had and save money at the same time."

The linearly shaped park will be a separate and distinct structure spanning the Seekonk River, accessible to pedestrians and bicyclists. The new park will feature a 3.4-meter (11-foot)-wide bike lane and a 2.1-meter (7-foot)-wide pedestrian path. By contrast, the previous bike path sat directly adjacent to traffic and was only 1.2 meters (4 feet) wide.

The pedestrian path will be placed waterside, while the bike lane will be closer to the new vehicular bridge, but built at a slightly higher grade than the pedestrian path to offer cyclists a clear view to the water. The bicycle path will run from India Point Park in Providence, over the Washington Bridge into East Providence, and continue 22.5 kilometers (14 miles) along the East Bay Bike Path to Barrington and Bristol.

In addition, the park will boast a 10.7-meter (35-foot)-wide overlook in the center of the span, from which visitors can admire the skyline of Providence, the residential tree-lined city of East Providence, and the sparkling upper Narragansett Bay and Seekonk River. The overlook and pedestrian walkway will feature benches, period lighting, landscaping, and rest areas.

In the January 25, 2002, edition of *The Providence Journal*, Ted Sanderson, executive director for the Rhode Island Historical Preservation & Heritage Commission, applauded RIDOT for its efforts. "[RIDOT] has come up with an amazing project to build the needed traffic lanes while saving a historic bridge and creating a new park," he said. "This may be unique in the Nation."

RIDOT Director Capaldi described the value of preserving part of the old bridge in the design: "This was a tremendous solution to our problem," he says. "We are talking about saving millions of dollars by saving the historic south facade. The two main piers and the one-time drawbridge operator's house are still in excellent condition, and it would have been a shame to take them down and dispose of them. We can now preserve all of this and incorporate these elements into the design."

Phasing Is Key

After conversations with contractors, RIDOT officials determined that it would be difficult, if not impossible, to secure bonding for a project with an estimated construction duration of 7 to 8 years. Therefore, Farhoumand says, "we decided we would phase the construction of the bridge. RIDOT would do the vehicular portion of the bridge first, and then in about 4 years, we are going to advertise the next phase of the project—the park phase."

When construction of the park begins, the south fascia wall of what had been part of the Washington Bridge roadway will be stabilized first. The existing concrete deck, sidewalk, and the columns standing on the arches will be removed, while the operator's house and the entire southern wall are retained. New hammerhead piers will be built on the existing piers, and a new superstructure of weathering steel and a concrete deck will be put into place. Steel will span over the remaining fiber-wrapped arches and be supported by hammerhead piers. The only thing the arches will then have to support will be their own weight.

"The north fascia wall will be constructed of a prefabricated, glass-reinforced concrete panel," Pavia says. "It will match the historic

RIDOT/Newport Collaborative Architects, Inc.

This computer-generated rendering of the future linear park on the new eastbound Washington Bridge 200 shows the separate bicycle lane on the left and pedestrian path on the right.

RIDOT/Newport Collaborative Architects, Inc.

To the right of the overlook, shown here, is the original operator's house from 1930, which will be restored for decorative purposes and incorporated into the park.

southern fascia stonework using form liners." The final phase of construction will include installing the architectural details, some of which will reuse stone and concrete elements from the original bridge.

A Winning Project

"This is one of the most complex projects RIDOT has ever undertaken," says RIDOT Director Capaldi. "What we are doing is essentially working on one bridge, but because of the phasing and the park, we are actually taking three bridges down and putting three back up."

The new five-lane Washington Bridge promises to improve traffic flow in the area, and the use of weathering steel and as few joints as possible will help make emergency maintenance a thing of the past.

In the end, the design compromise helped avoid the high cost of purchasing rights-of-way and achieved department goals for historic preservation—saving taxpayers more than $35 million in construction costs. Most of the construction will take place off the roadway, reducing delays for motorists. A portion of a historic bridge will remain intact, and the public will gain a new park. In addition, waterways will remain undisturbed because the old foundations will not be removed.

"In keeping with the department's policy of context-sensitive solutions, the overall design of the facility will honor the era of craftsman bridge building," says Wilfrid L. Gates, Jr., chairman of Gates, Leighton & Associates, Inc., the landscape architectural consulting firm working on the project. "The preservation of the historic south facade, the selection of materials, and the onsite interpretation of its history will define and signify RIDOT's enlightened transportation planning for the 21st century."

Dana Alexander Nolfe has been the chief public affairs officer for RIDOT since 1997. She oversees all aspects of RIDOT's public relations activities including special events, media relations, media campaigns, news releases, and speech writing. Nolfe also serves as an adjunct professor at Bryant University in Smithfield, RI, where she teaches both graduate and undergraduate courses in communications. Nolfe's professional experience includes other teaching positions and work for various television stations, including production work for programs such as ABC's *20/20* and *World News Tonight*. Nolfe holds a bachelor of arts degree in communications and political science from Queens College in Flushing, NY, and a master of arts degree in broadcast news journalism from New York University in New York City.

Designing Tomorrow's Pavements

by John D'Angelo, Suneel Vanikar, and Katherine Petros

The new guide and software may become the national approach for creating and rehabilitating roadway surfaces.

In the early 1960s, the American Association of State Highway Officials (AASHO)—the precursor to the American Association of State Highway and Transportation Officials (AASHTO)—conducted the road tests that would become the basis for most pavement designs. More than four decades have passed since the AASHO study, and many methods and design procedures have evolved, stemming from new technologies and the increasing traffic demands on pavements.

Researchers are now incorporating the latest advances in pavement design into a new set of design procedures. Over the past 7 years, these researchers have been developing, testing, and refining the data and procedures that will become the new *Mechanistic-Empirical Pavement Design Guide*.

The new guide was developed through the National Cooperative Highway Research Program (NCHRP Project 1-37A). Recently, NCHRP submitted the guide to AASHTO for adoption within the next 2 to 3 years. Currently, NCHRP is distributing the design guide and associated software as a research product at www.trb.org/mepdg for agency representatives and other users to acquaint themselves with the material.

The new guide offers several dramatic improvements over the current one, AASHTO's 1993 *Guide for Design of Pavement Structures*. "The most significant change is that it offers a much more sophisticated design procedure, using mechanistic-empirical analysis," says Dr. Leslie Myers, asphalt pavement engineer with the Federal Highway Administration's (FHWA) Office of Pavement Technology and a member of the FHWA Design Guide Implementation Team (DGIT). A mechanistic pavement design approach uses a model to calculate the response of the pavement to traffic loads. A mechanistic-*empirical* approach uses both experimental data and mathematical models to predict pavement performance. Myers continues, "These procedures should support a higher degree of predictability in pavement performance, since they are based on fundamental material properties."

Another major improvement is that the new guide will enable designers to evaluate pavement rehabilitation projects, whereas the current guide only handles new pavements. NCHRP indicates that approximately 73 percent of the Nation's pavement design dollars are spent on rehabilitation, so the

Analysis of typical pavement rehabilitation projects is not possible with the current pavement design guide. The new guide will enable evaluation of both simple and complicated rehabilitation projects, such as this flexible pavement rehabilitation project in eastern Oregon (left) and this rigid pavement rehabilitation on I–40 in Raleigh, NC. *Photos: (left) Oregon DOT, (right) FHWA.*

ability to evaluate rehabilitated pavements is a critical feature.

The guide will include a user-friendly software package designed for flexibility, offering engineers three levels of input data from which to choose depending on the amount of available data. Below is an overview of the limitations of the current design procedures and highlights of the new guide's features.

Limitations of the AASHO Road Test

The new design guide eventually will replace the existing one, which is based purely on empirical principles. Using an empirical approach, the pavement designer determines the relationships between design inputs (such as loads, materials, layer configurations, and the environment) and pavement failure through field observations and experiments. An empirical analysis, however, does not establish the fundamental basis for the relationships between variables and outcomes.

The empirical equations used in the 1993 AASHTO guide are largely a result of the original road tests performed by AASHO from 1958 to 1961, in what was the largest experiment on highway pavements of its time. The study evaluated the performance of both portland cement concrete (PCC) and asphalt concrete pavements using known thicknesses under traffic loads of known magnitude and frequency.

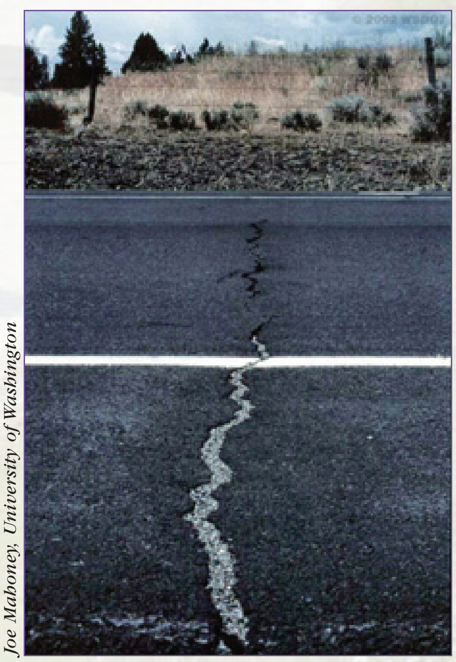
Although the empirical methods for pavement design that ultimately resulted from the study represented a giant leap forward, the road test had a number of limitations that constrain its continued usefulness as a basis for modern designs. Because the test was conducted at one specific geographic location, in Ottawa, IL, it does not capture the effects of differences in climatic conditions on pavement performance. For example, pavements in the road test experienced a significant amount of distress (such as thermal cracking) due to cold weather and the spring thaw. However, since a significant portion of the country, including most of the south and west, does not generally experience these extremes, this type of distress is not an issue.

Another limitation is that all of the variables in the test (such as vehicle characteristics and assumptions about traffic loads and pavement materials) were representative of the conditions of the late 1950s. Many of these assumptions are outdated today.

Mechanistic-Empirical Design Approach

A primary difference between the new guide and previous versions is that it is based on a mechanistic-empirical approach. "Using real traffic data, local climate conditions, material behaviors, and known field performance, engineers can predict the future performance of new pavement sections more accurately," says Myers.

"One of the premises of the current empirical design procedure is that if you have an increasing amount of traffic then you need an increasing amount of thickness in the pavement," says Dr. David Newcomb, vice president for research and technology at the National Asphalt Pavement Association. "What we know in reality, and what the mechanistic-empirical approach can model, is that you can hit a point of diminishing returns. In other words, at some traffic level, increasing thickness is not going to buy you anything."



Joe Mahoney, University of Washington

This pavement is suffering from thermal cracking, a typical pavement distress due to freezing temperatures. Local validation and calibration of distress predictions are key to the successful implementation of mechanistic-empirical design.

The new approach also takes into account the properties of the actual materials that will be used in the design. "Take for example an asphalt pavement design," Myers says. "The new design procedure takes into account the asphalt binder content, binder grade, and the aggregate gradation. It takes real material properties and brings them into the analysis tool, which can then be used to make decisions on what the ultimate pavement design should be. Likewise, for a PCC pavement design, the guide uses detailed material properties, such as the coefficient of thermal expansion, to project the expected performance of the pavement."

The mechanistic-empirical procedures also can evaluate the potential impacts of construction control. "If you have a pavement where a lot of segregation has taken place in the asphalt—separation between the coarse and the fine particles—that could affect the variability of the material properties," Newcomb says. "The modeling inputs can include these kinds of material properties, so you can get a sense of what the segregation would do to the performance of the pavement."

Predicting Pavement Performance

Another major departure from the current design guide is that the new guide will provide analysts with predictions for pavement performance rather than pavement thickness values. "When you run a design using the current procedures, you're given thickness values for each of the layers in your pavement design," Myers says. "The new guide is more of an analysis tool. It doesn't give you the thickness of a layer, but instead it predicts pavement performance. So for a layer of concrete, the user inputs a trial layer thickness and other design data, and the procedure tells you how much cracking, punchout, or other pavement distress you'll see for the life of your pavement."

The results of the analysis then can be used to refine the pavement design. "It's an iterative process," Myers says. "If the analysis indicates that cracking will occur, a thicker concrete pavement or a shorter joint spacing may be warranted. The users come up with a different design, rerun the analysis, and evaluate the

Material tests provide valuable inputs to the new design analysis tool. This concrete specimen awaits testing in a water bath, which will measure the change in length of the specimen over a given temperature range to determine the concrete's coefficient of thermal expansion (CTE). The amount of calculated curling stress is sensitive to CTE values, making it an important parameter in the software program for designing rigid pavements.

Matby Construction

The new procedures enable designers to analyze the impact of construction conditions on pavement performance. Here, designers are sampling hot-mix asphalt from the back of a paving truck.

results again. They can keep making changes, whether to the smoothness or the thickness of the pavement, or the materials they use, until they come up with an acceptable design that meets the distress criteria determined for their local conditions."

Pavement Rehabilitation

What about projects to rehabilitate existing pavements? With the majority of the Nation's pavement design dollars spent on rehabilitation, another critical enhancement offered by the new guide is the ability to analyze rehabilitation designs. Specifically, the guide includes procedures for evaluating existing pavements and recommendations on rehabilitation treatments, subdrainage, and foundation improvements.

"Take, for example, a concrete pavement rehabilitation project that involves rubblizing the pavement and putting additional concrete on top—or even a flexible pavement rehabilitated with PCC whitetopping," Myers says. "Using the current design procedures you couldn't analyze that. But with the new design guide procedures you can."

One reason a rehabilitation design is possible now is because the new procedures enable the analyst to indicate the smoothness of the existing pavement, typically characterized by the International Roughness Index (IRI). "The analyst enters information into the model on the existing pavement, including the existing IRI, and planned rehabilitation," Myers says. "The model then predicts how the rehabilitated pavement will perform, outputting a new IRI and indicating when cracking might occur."

The new design guide also includes procedures for analyzing more pavement types than the existing guide and software. Although the existing guide includes procedures for evaluating flexible and rigid pavements, the new guide and software include procedures for these two types of pavements, as well as semirigid composite pavements.

And according to NCHRP, the procedures and software provide consistent trial design inputs for each pavement type. The rigid and flexible pavement modules have the same inputs and interface wherever possible. The consistency between the rigid and flexible modules enables the user to experiment with both rigid and flexible solutions to design problems.

Benefits of a Mechanistic-Empirical Pavement Design Approach

- Provides more reliable predictions of pavement performance
- Evaluates both existing pavements (for rehabilitation) and new pavement construction
- Incorporates daily, seasonal, and annual changes in local materials, climate, and traffic
- Potentially reduces life cycle costs
- Evaluates the impact of new load levels and conditions more effectively
- Uses data throughout the country to calibrate models
- Includes ability to calibrate models for local conditions
- Uses pavement responses to actual modes of failure rather than one generic model based solely on roughness
- Assesses the impact of construction variability (such as initial smoothness, early opening to traffic, and construction temperature)
- Relies on actual engineering properties of materials that relate better to pavement performance
- Facilitates the evaluation of new materials
- Provides material databases for updating input values that can be refined as information becomes available

Local Conditions, Local Calibration

Perhaps one of the most valuable improvements in the new design guide is that it can accommodate data on local conditions, such as traffic and climate. According to Linda Pierce, a pavement engineer at the Washington State Department of Transportation (WSDOT), including local climate data will be helpful in her pavement designs. "Washington State has microclimates in every climate area," she says. "I can be at the bottom of a hill, and 5 miles

[8 kilometers] away, on the top of the hill, it's an entirely different climate region. And yet in my current design procedure, it's all classified as the same climate. With the new procedures, I can actually go to a weather station that's within 5 miles of the project [to obtain climatic data]."

The software also can be calibrated to reflect the properties of local pavement materials. "The new design guide is based on data from the Long-Term Pavement Performance [LTPP] program and other field and lab performance data," Myers says. "But an agency can take its own material, complete a series of laboratory tests on it, and then use those as the inputs instead."

Washington State plans to do just that. "The researchers did a fantastic job of pulling together as much data as they possibly could from all over the country to help generate the models," says Pierce. "But some States don't have the quality of aggregate that is available in Washington State. So we will calibrate the model to our own material properties. And when it's adopted by AASHTO, I suspect that there will be a strong recommendation that the models be calibrated to local conditions."

Mechanistic-empirical pavement design incorporates data from actual laboratory tests. (Left) A technician prepares asphalt mixture samples. (Right) A researcher runs the Simple Performance Tester to evaluate an asphalt mixture for its response to permanent deformation (rutting) and fatigue (cracking).

Potential Cost Savings

The mechanistic-empirical procedures should lead to a longer life for many pavements. According to FHWA, pavements typically are designed for a 20-year period of performance, although some States use 30 to 40 years. Some pavements, however, last much longer. These may be called long-life pavements.

The NCHRP research team that developed the new guide estimates that pavement performance will improve considerably by using the new design procedures, potentially resulting in substantial cost savings. For example, NCHRP estimates that the new procedures for pavement rehabilitation alone could result in nationwide savings of $1 billion per year over the next 50 years.

A major source of potential cost savings stems from reducing premature pavement failures. The research team's analysis assumed that early pavement failures (pavement life of less than 10 years) would drop from 5 percent to 0.5 percent with the new design procedures. The analysis further assumed that using the new procedures would add an additional 5 years to the current performance life standards of 10 to 30 years.

These predictions may, however, represent long-term results, and States may not experience dramatic near-term cost savings. "For some States it will be cheaper, for other States it will be more expensive," says Pierce from WSDOT. "It's all in how you're currently designing pavement, and whether you're overestimating or underestimating traffic levels, material properties, or climatic effects."

Software: Three Levels of Design

The NCHRP research team designed the software to be user-friendly and flexible. As a member of the panel reviewing the new guide, Pierce also evaluated the software. "It's actually a much better software program than we ever anticipated," she says.

The software features three levels of data input from which a pavement engineer can choose, depending on the amount and type of data available. The most complex is a Level 1 design, which represents a full mechanistic-empirical procedure. "A Level 1 design means you've done all

Texas DOT

Surface cracking in asphalt pavement, like that shown here, is one of the distress forms that designers will be able to predict using the mechanistic-empirical pavement design tool.

A work crew rehabilitates a flexible pavement using the whitetopping approach on I–40 near Henryetta, OK.

Introducing…the Design Guide Implementation Team

The Federal Highway Administration (FHWA) has taken a leading role in helping implement the new design guide by creating the Design Guide Implementation Team (DGIT). The team's purpose is to inform and educate FHWA division offices, State highway agencies, industry representatives, and others about the new design guide and assist with implementation.

In January 2004, FHWA distributed a survey to each division office to assess the readiness of the States to adopt and implement the new guide. The results indicated that about 70 percent of respondents believed that their States would be receptive to adopting the mechanistic-empirical approach. A number of respondents, however, requested additional information before they would be ready to use the new guide. In response, the DGIT developed a program to help States understand and implement the new procedures.

DGIT Workshops

FHWA is holding a series of workshops for Federal and State pavement designers and industry and academic partners over the next couple years. "The workshops provide an overview of what is different in the new guide, versus the current design procedures," says Dr. Leslie Myers, a member of the DGIT. "We offer details regarding what you really need to run a mechanistic-empirical design, the testing involved and the lab equipment needed, and the expected benefits."

The workshops include real-life examples using the new guide. "We run through examples of mechanistic-empirical designs on a flexible pavement, a rigid pavement, and a few rehabilitation pavements," Myers says. "Our vision is to raise awareness and assist the States to show them how they can put together an implementation plan and begin using the new guide effectively."

Future DGIT Activities

As agencies use and assess the guide, the DGIT will provide technical assistance to the States. The team will assist with technical issues, such as local calibration, new materials, and unique load configurations, and arrange small working sessions to address local concerns.

FHWA's new and improved Mobile Asphalt Pavement Mixture Laboratory and the Mobile Concrete Laboratory will help employ and demonstrate the concepts covered in the new guide. "The labs will give States a preview of what they can to do to begin using the design guide in terms of Level 1 materials testing and how they can make implementation easier," Myers says.

Attendees at the World of Asphalt 2004 Show & Conference in Nashville, TN, visit the information booth sponsored by FHWA and the Design Guide Implementation Team.

The Team

Members of the team are Katherine Petros from FHWA's Office of Infrastructure R&D at the Turner-Fairbank Highway Research Center, Leslie Myers and Sam Tyson from FHWA's Office of Pavement Technology, and Monte Symons and Timothy Barkley from FHWA's Resource Center.

For more information, visit www.fhwa.dot.gov/pavement/dgit.htm.

the high-level testing and evaluation of pavement materials in the laboratory," Pierce says, "and you've quantified the material properties according to the design procedures." Users can conduct the Level 1 design for any type of pavement project, assuming the engineers have the capability of gathering the traffic data and have the equipment necessary to test the pavement materials.

The Level 2 design relies on both field data and default values from the design guide. According to Myers, a Level 2 design enables users to provide some information, for example, traffic data from a weigh-in-motion station, but they do not need the equipment to do testing on soils or other components. The procedure will take any real data, or a designer can use the default inputs, which are based on national averages of long-term pavement performance data, for the data that cannot be measured. "So it is a bit of a mixed analysis," Myers says.

The final level of design is Level 3, which relies completely on default values from the models and is the closest to an empirical analysis, most similar to what is done now. Level 3 is flexible because it does not preclude someone from using the new procedures and guide if they do not have all the test data from the laboratory or the field data. They still can use the default values.

Ideally, however, pavement engineers should work toward the Level 1 analysis. Washington State plans to approach the new procedures incrementally. "I'm probably going to start my State out at Level 3, the very entry level of the data inputs," says Pierce, "and then enhance it with more data to get it to a Level 2 and Level 1 analysis."

The software is in English units, and it includes a user's manual and onscreen help. The software developers designed the program to run on Microsoft® Windows® 98, Windows 2000, Windows NT®, and Windows XP®, and the results can be output both as hardcopy and electronically in either HTML or Microsoft Excel workbook formats.

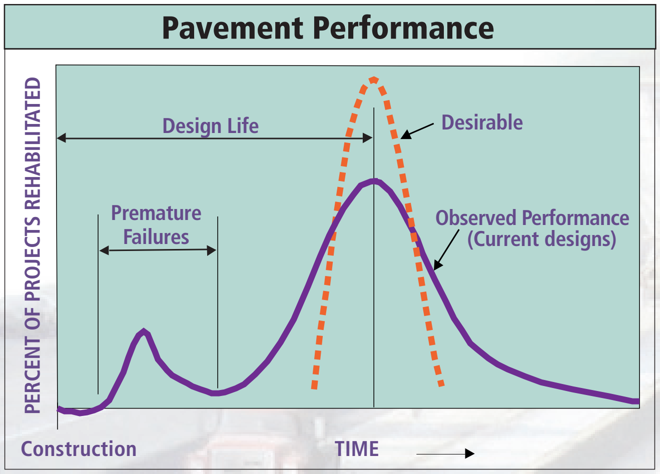
"[The software] is a great design as far as the way they have laid out the program and the way that it processes," Pierce says. "It's actually pretty slick. And it's significantly better than the existing software that goes with the 1993 guide."

Research Focuses on Critical Inputs

Although a Level 1 design requires many more data inputs than a Level 3 design, some inputs may be more critical than others. Dr. Kevin Hall, a professor in the department of civil engineering at the University of Arkansas, is working on a sensitivity analysis of the procedures and models used in the design guide. His research involves establishing a baseline set of values for all the inputs the user is expected to provide, then varying a single input across a range of values to see how much that variable impacts the resulting answers. Other researchers and agencies also are undertaking similar efforts.

Hall acknowledges that one limitation of this approach is that it does not capture interactions between inputs. "Two inputs into the procedure for concrete pavement design are the unit weight and the compressive strength," Hall says. "Our approach changes only one of these inputs at a time, whereas in the real world there may be a relationship between concrete strength and unit weight such that if one of the values varies, the other might also [vary]."

But even with the limitations of the approach, according to Hall the research should result in valuable information that will be useful to pavement designers. "We can check to see if the models and procedures contained in the design guide give reasonable answers," he says. "For many of the inputs, a pavement engineer will have an intuitive feel for how that input should affect the resulting answer. In concrete pavement design, for example, increasing the compressive strength of the concrete should improve the performance of the pavement in many areas. The other potential value of this analysis is to identify any inputs that do not seem to have a significant effect on the resulting answer."



Source: National Cooperative Highway Research Program

The graph illustrates the performance of existing pavements, (solid black curve) versus desirable performance (dotted curve). Under the current procedures for pavement design, a sizable number of pavements experience premature failure, shown in the curve on the left, and require rehabilitation less than 10 years after construction. Using the mechanistic-empirical approach, however, (shown in the dotted curve on the right) researchers expect that no pavements will experience premature failures.

In other words, Hall's research will help identify inputs that do not seem to have much impact on predictions about pavement performance. "If we can identify those inputs that fall into such a category, we can tell designers to try and obtain reasonable values for those inputs, but not to spend large amounts of time or money refining the input value since the system is not significantly sensitive to the value anyway." This could result in cost savings for agencies during the development of designs.


Resilient modulus test in progress on a sample of subgrade soil.

What States Can Do Now

Although NCHRP released the new design guide and software during the summer of 2004, several years may pass before AASHTO officially approves it. While waiting for AASHTO's approval, States can begin getting ready for the improved design approach. FHWA established the Design Guide Implementation Team (DGIT) to help States prepare.

Some States are well on their way. The Montana DOT is midway through a 5-year research effort that involves collecting new data and conducting extensive testing of the most common materials used in Montana. According to Jon Watson, a pavement engineer with the Montana DOT, the State plans to use the data and analysis from the project to calibrate the new design guide model locally.

According to Pierce, Washington State also is taking steps to prepare for the release of the new guide. "I will use my existing software to improve my comfort level and help in the calibration procedure," she says. "I am actually starting the calibration process now and getting a plan sketched out on how we are going to do this."

Because Pierce has been reviewing the design guide and software, her State may be further ahead than others. However she has some advice for other States. "Take one piece at a time and try not to make the transition to the new design procedures a much larger project than it actually is," she says. "Take the new procedures in sizable chunks, evaluate and analyze one feature, and go on to the next."

"I think the new design guide is a great thing," Pierce says. "Although it does not include everything yet, it is a good move forward, and a lot of people will be happy with it."

John D'Angelo is an asphalt materials engineer in the Office of Pavement Technology at FHWA. He has been with FHWA for 27 years. For 12 years he was involved with the implementation of Superpave™ through the former Strategic Highway Research Program. He has published numerous papers on material testing and quality control.

Suneel Vanikar leads the concrete group in the Office of Pavement Technology at FHWA. An FHWA employee for more than 20 years, he is responsible for activities related to concrete pavements and materials, including policy, guidance, and technology transfer. He earned his M.S. degree in civil engineering from Colorado State University.

Katherine Petros is the team leader of the Pavement Design and Performance Modeling Team at the FHWA Turner-Fairbank Highway Research Center. She also chairs FHWA's Design Guide Implementation Team.

For more information, visit www.trb.org/mepdg or contact the FHWA Design Guide Implementation Team at dgit@fhwa.dot.gov.

Learning from the 2003 Blackout

Massive power outages offer multiple lessons on how to position the transportation system for optimal performance during disasters.

by Allan J. DeBlasio, Terrance J. Regan, Margaret E. Zirker, Kristin Lovejoy, and Kate Fichter

The largest power outage in U.S. history rolled across much of the Northeast from Detroit to New York City on a hot and humid Thursday in August 2003. The massive power outage left a swath 6,000 kilometers (3,700 miles) long—including portions of Michigan, Ohio, Pennsylvania, New Jersey, New York, Connecticut, Vermont, and Canada—in the dark. In New York City, workers poured out of the highrises only to find the streets gridlocked, because traffic signals at all of the city's 11,600 signalized intersections had ceased to operate. The New York subway system ground to a halt, stranding more than 400,000 passengers in tunnels. The city's extensive commuter rail network also closed down, leaving few options for routing stranded customers back to their homes in New Jersey and Connecticut since approximately three-fourths of work trips into Manhattan are made using transit.

Traffic signals and public transit are only part of the transportation facilities that depend on electricity. Other systems include tunnel lights and ventilation; intelligent transportation systems (ITS) equipment such as cameras, loop detectors, variable message signs, and electronic toll collection equipment; and pumps to control flooding in depressed roadways.

In Detroit, MI, the August 14, 2003, power outage hit just at the beginning of rush hour, leading to heavy congestion on miles of freeways. By the next day, a heavy rain had flooded several sections of depressed freeway because the sump pumps used to remove water from these sections had no power, and backup generators were unavailable. Cameras and variable message signs were not operational as well, making it difficult for managers to gather and communicate information to the public—except through the lenses of cameras on news helicopters.

Restoring transportation operations is vital to safety, freight movement, and national security. "Historically, transportation has been viewed as an important support function during disasters," says the Federal Highway Administration's (FHWA) Emergency Transportation Operations Team Leader Vince Pearce. "But the more we look at large-scale situations, the more we see that if transportation doesn't work right, it's too hard for other responders to do their jobs. If we can't get the fire trucks and ambulances to the scene, we can't put the fires out or help the injured. Transportation must work at its absolute best in these kinds of situations, and our objective is to help the transportation community bring their resources to bear at the most important time."

Pedestrians leaving Manhattan during the 2003 blackout flooded New York's 59th Street Bridge to Queens. *Photo: AP/Wide World Photos.*

How Did the Blackout Happen?

Despite the heat and humidity on August 14, the network of electric transmission lines in the East was carrying a standard load for that time of year. Shortly after 2:00 p.m., a brush fire caused a transmission line south of Columbus, OH, to go out of service. This outage was followed at 3:05 p.m. by the failure of a transmission line connecting eastern and northern Ohio, and then a second line failed in the same area. As more and more sections of the electrical network disconnected from the grid, the blackouts accelerated.

At 4:10 p.m., the system connecting the region south of the Great Lakes, including the cities of Detroit and Cleveland, across the country to New York and New Jersey experienced a profound failure. Within the space of a single minute, many transmission lines failed throughout the entire area, creating a cascading effect in which lines sequentially overloaded and then failed.

Airports halted operations, and elevators stalled midride. Water systems shut down. The communications network was disrupted, since many cellular and other telephone systems ceased to work. Stranded commuters spent the night in train stations, hotel lobbies, and emergency shelters. Others spent many hours trying to get home by foot or ferry boat.

The first question on many peoples' minds, including speculations transmitted by the press: Was this emergency related to national security? The guiding priority in

Emergency Transportation Operations Program

The August 14 blackout—massive as it was—was only one of 56 federally declared disasters in 2003. To realize the enormity of this statistic, consider that the Nation averaged more than one catastrophic event *per week* that year: hurricanes, floods, landslides, wildfires, tornados, avalanches, ice storms, and power outages. The impact on the U.S. transportation system is incalculable.

To address the effect of major emergencies on transportation, FHWA's Office of Transportation Operations initiated the Emergency Transportation Operations Program in 2001 to examine how the transportation system is used during those situations.

"The program's underlying concept has two legs," says Vince Pearce, the team leader. "First is that every incident affects traffic even if it doesn't occur on the transportation network. Second, the transportation network is the route through which responders get to the scene and how they get the ill and injured out to proper care."

Under the Emergency Transportation Operations Program, FHWA initiated a series of case studies on the effects of major emergencies on surface transportation, the actions taken to respond, the rationale for those actions, and the ways that technology can be applied to improve those responses. To date, the reports on six case studies are completed or are nearing completion, four produced by the USDOT's John A. Volpe National Transportation Systems Center in Cambridge, MA, and two by Scientific Applications International Corporation in Washington, DC:

- Earthquake, Northridge, CA—January 17, 1994
- Rail Tunnel Fire, Baltimore, MD—July 18, 2001
- Terrorist Attack, New York City, NY—September 11, 2001
- Terrorist Attack, Washington, DC, Metropolitan Area—September 11, 2001
- Blackout, New York City Metropolitan Area—August 14, 2003
- Blackout, Great Lakes Region—August 14, 2003

Volpe Center staff also completed a cross-cutting study covering the first four case studies and a comparative analysis of all six studies.

FHWA used the findings from the case studies during workshops and exercises to spread the lessons learned and a wake-up call about the need to prepare for the unexpected. The FHWA program is bringing together relevant policies, protocols, procedures, and practices at the national level by working with the U.S. departments of Justice, Homeland Security, and Health and Human Services. And it is helping the State and local transportation communities to do the same in their jurisdictions. The program is a multimodal undertaking since evacuations involve not only highway vehicles—cars, trucks, and buses—but also commuter trains, ferry boats, and even movement of pedestrians.

every emergency is the protection of life, but many transportation staff in the affected areas initially feared a terrorist attack. Reaction and response to a terrorist attack would be different from a nonsecurity-related emergency, making it vital to communicate the causes of failure as quickly as possible. Once the causes of the blackout became clear, agency managers shifted their focus from security to safety and then to mobility.

The Big Apple at a Standstill

With only a few exceptions, the ITS equipment operated by New York transportation agencies went down. The George Washington Bridge, which receives power from multiple locations, remained operational. The bridges and tunnels run by the Metropolitan Transportation Authority (MTA), which had backup generators, also continued to function.

Because of lessons learned from past emergencies, the agencies responsible for the city's transportation system had response plans in place. Previous major blackouts, preparations for the year 2000 (Y2K), and the events of September 11, 2001, had prepared the region to deal with significant disruptions to its transportation network. But the plans did not anticipate the scope and duration of the August 2003 blackout.

With police, fire, and emergency response personnel focused on freeing people trapped in stiflingly hot elevators and dealing with other life-threatening situations, traffic management took a secondary priority. In many cases, citizens stepped in to direct traffic at major intersections when police were unable to reach their assigned stations. Under emergency operating procedures developed after September 11, many of the tunnels and bridges into Manhattan were immediately closed or access to them was restricted. Each of the region's 13 traffic management centers is linked through an interagency remote video network of more than 400 cameras. Although the network maintained connections with two-thirds of the centers, the system was compromised because most of the cameras in the field failed due to the lack of backup electricity.

Within 5 minutes of the blackout, Con Edison, Inc., personnel had notified NYC Transit managers that the power outage was extensive and potentially long in duration. Evacuation of subway passengers began in the next 10 minutes.

As on September 11, water ferries were overwhelmed with passengers trying to leave Manhattan for New Jersey. Buses quickly became caught in the traffic gridlock.

Most businesses were closed the next day, keeping the traffic volumes light. Power was restored to all of New York City at 9:30 p.m. Friday night, approximately 29 hours after the blackout began. The NYC Transit subway system resumed full service by 6:00 a.m. on Saturday morning. It was not until Sunday night that the New York City Department of Transportation (DOT) completed the task of inspecting all of the city's traffic signals.

Blackout Disrupts Detroit Traffic

The Michigan Intelligent Transportation Systems (MITS) Center, managed by the Michigan DOT, oversees 290 kilometers (180 miles) of freeways in the Detroit area. The Detroit DOT operates approximately 430 buses during peak hours and the suburban transportation agency an additional 300 fixed-route buses and about 100 demand-responsive vehicles. The suburban vehicles are equipped with automatic vehicle locator equipment linked to computer-automated dispatching. The Detroit People Mover, an elevated monorail, operates in the downtown.

The blackout hit Detroit at rush hour, so traffic that normally would have been staggered throughout the evening was concentrated in the period immediately after the beginning of the blackout. By 4:15 p.m., the Detroit-Windsor Tunnel across the U.S.-Canadian border was closed down. The tunnel is served by four separate and independent power feeds. "It was the first time in anybody's memory that all four feeds failed," says Neal Belitsky, executive vice president and general manager of the Detroit & Canada Tunnel Corporation. Belitsky adds that the tunnel operators followed a preplanned protocol and evacuated the tunnel in less than 15 minutes.

Electrical service was restored in some parts of the region as early as Thursday evening and in most areas by Saturday night. The power was not immediately stable when it returned. Rolling outages across the region meant that some equipment had to be reset more than once.

Impacts on Other Cities and States

Transportation impacts on other States like Vermont and Pennsylvania were minimal. In New Jersey, the blackout affected power in five counties in the New York City metropolitan area, but the transportation system was relatively unaffected except for movement of commuters out of New York into New Jersey. In Pennsylvania, emergency operations centers were partially mobilized. But by 1:10 a.m. on Friday, August 15, almost all power in Pennsylvania was restored.

In Cleveland, public officials were unable to use the emergency response center immediately after the start of the blackout due to a lack of backup power. A portable generator arrived about 8 hours later. Following the loss of power, most traffic signals in the city went dark, which produced gridlock at many intersections. Off-duty and auxiliary police officers assisted in directing traffic,

Opportunities for the Electricity Sector

The entire U.S. electricity network is so interconnected that points on the grid are separated by milliseconds. Subsequent to the massive August 14 power outage, the U.S. General Accounting Office (GAO) released a report in November 2003, "Electricity Restructuring: 2003 Blackout Identifies Crisis and Opportunity for the Electricity Sector." Among GAO's recommendations for congressional action are the following:

- Encourage the use of consumer demand response tools in retail markets to avoid scarcity during periods of high demand and consequent reduction of the reliability of the system.
- Consider empowering a regional entity to resolve State and locality disputes over siting plants and lines to add infrastructure.
- Clarify the Federal Energy Regulatory Commission authority over wholesale markets and transmission lines, and move toward standardization of market rules.
- Reduce the uncertainties about restructuring's future, identifying milestones or a timeline.
- Increase the regulated rate of return for investments in transmission upgrades.
- Consider encouraging distributed power sources, diversity in energy sources, and improved conservation measures.

Volpe National Transportation Systems Center

The shaded area of this map shows the region of the United States affected by the August 14, 2003, electrical power loss.

Key Decisions by NYC and NJ Transportation Agencies

On and after August 14, 11 transportation agencies in the NYC metropolitan area collaborated with other government agencies to make the following strategic decisions.

Agency	Key Decisions
Information FOR Motorists (INFORM)	Implemented emergency management procedures and expanded hours of operation for highway emergency local patrols.
Joint Transportation Operations Center (NYPD, NYC DOT, NYS DOT)	NYPD reassigned approximately 2,000 traffic agents to begin directing traffic.
Metropolitan Transportation Authority (NY MTA) Bridges and Tunnels	Switched to backup generator power and continued to operate. Reversed lanes in crossings to accommodate buses returning to Manhattan, and suspended outbound tolls.
New Jersey DOT Traffic Operations-North	Initially lost power but within an hour was displaying highway advisories on its variable message signs.
NJ TRANSIT	Implemented its preestablished plan for communications outages, established a bus "bridge" to replace the Hoboken light rail system, and started a "load and go" operation from the Port Authority Bus Terminal in Manhattan to the Meadowlands Stadium.
New York City Transit-Bus	Started a shuttle service from Penn Station to the Long Island Rail Road station at Jamaica, sent buses to major subway stations, and suspended fares.
New York City Transit-Paratransit	Continued operations and prioritized patrons needing life-sustaining services.
New York City Transit-Subway	Began the evacuation of 400,000 subway passengers at 4:20 p.m.
Port Authority of New York and New Jersey	Activated the Emergency Operations Center, closed or restricted access to facilities that had lost power.
Port Authority Trans-Hudson Corporation	Identified the location of its 19 en-route trains and then shut down the system and evacuated at 4:30 p.m.
Transportation Operations Coordinating Committee (TRANSCOM℠)	Issued facility status bulletins by fax, e-mail, and phone, including a toll-free number.

and emergency generators were later used to power some of the traffic signals.

Most of the congestion had cleared from the downtown area by 6:30 p.m. on Thursday. In fact, Howard Huebner, district roadway service manager with Ohio DOT's District 12, says, "I've never seen Cleveland empty so quickly." By early evening on Saturday, full service was restored to the Cleveland area.

Although all emergencies share certain similar characteristics, each is unique and provides the transportation community with new insights into how to prepare, how to set priorities, and how to respond. The 2003 blackout has added to the growing base of knowledge. The findings of the New York area and Great Lakes region case studies offer lessons learned in six areas: planning and preparation, operating decisions, agency coordination, the role of advanced technology, technical communications, and system redundancy.

Planning and Preparation

The first lessons learned from the August 14 blackout relate to planning. To respond effectively to a catastrophic event, transportation agencies need to have a plan of action in place to handle the emergency and the process of restoration once the crisis is over. Preparation includes drafting an emergency response plan and revising it as necessary, stockpiling emergency items, and rehearsing crisis scenarios.

One of the key themes related to emergency response plans is the need to learn from previous events and to incorporate that learning into an agency's response plan. The experiences of Y2K and September 11 encouraged many transportation managers to draft their first-ever emergency response plans. For others, the earlier events led to identifying or rectifying any weaknesses in the emergency plans they already had, efforts that proved invaluable during the 2003 power outage. But some agencies' plans still lacked enough depth to address an emergency as prolonged as the August 14 blackout.

Internal planning within an agency is essential. Emergencies happen without warning and do not always go as planned, so being able to rely on agency staff at all levels to make timely decisions is critical, even if they lack complete knowledge of all the circumstances. Response plans need to make it possible for staff members to know their responsibilities in an emergency and to step into their assigned roles quickly and easily, with a minimum of confusion and wasted time. Predetermined roles and clear chains of command are essential, as are alternate methods of communication.

Several agencies realized the need to develop plans in the event that communication is lost (NonComm plans). During roll call, employing a NonComm plan, New York City police officers in the traffic division are assigned locations, and they must proceed to those assignments during an emergency without being notified. At the Port Authority of New York and New Jersey, executive managers are notified by e-mail, blast fax, and phone in the event of an emergency. During the 2003 blackout, several managers reported to the emergency operations center without being called because they knew the agency's procedures.

Because transportation agencies are interdependent, planning is most effective if done in concert with all the agencies that make up the transportation network, as well as nontransportation agencies. For example, after the blackout, the Detroit-Windsor Truck Ferry staff began working more closely with U.S. Customs and Border Protection officers to plan more effectively for emergencies that affect the crossing of commercial freight between Canada and the United States.

Emergency response plans need to consider the movement of pedestrians as well as vehicles. People walking through highway tunnels and across bridges can prevent emergency vehicles from entering those facilities. To help solve this problem, planning needs to include the identification and publicizing of transportation hubs where pedestrians can assemble for taking buses out of the city. During the blackout, transit staff transported pedestrians across New York bridges and tunnels by bus. In future emergencies, officials foresee using a public address system to tell pedestrians where to catch transportation out of the city.

Stockpiling appropriate supplies and equipment is the second component of preparation. When stockpiling supplies, officials advise not to neglect the small items. Agency representatives mentioned the need to stock water and high-energy food bars for staff members who have to operate emergency operations centers over an extended period of time. When one Detroit official, Ron Ristau, director of service development at the Suburban Mobility Authority for Regional Transportation (SMART), tried to purchase bottled water for his staff during the blackout, he had to settle for buying "everything in sight that had liquid in it." Other officials highlighted the need for extra flashlights and charged batteries for cell phones, pagers, portable radios, and portable computers.

Key Decisions by Detroit Transportation Agencies

On and after August 14, eight transportation agencies in the Detroit metropolitan area collaborated with other government agencies to make the following strategic decisions.

Agency	Key Decisions
Ambassador Bridge	Used existing backup power to maintain operations throughout the duration of the blackout.
Detroit-Windsor Truck Ferry	Continued operations with reduced communications capabilities, processing documentation by hand rather than electronically and suspending online reservation and advanced notification systems.
Detroit-Windsor Tunnel	Used preplanned emergency protocol to close and evacuate the tunnel within 15 minutes of the blackout.
Michigan DOT	Powered down all computer network operations to prevent the system from crashing and communicated with the Governor's office by landline telephone.
Michigan ITS (MITS) Center	Ceased regular operations in order to reserve staff members for activities associated with the restoration of power.
Oakland County Emergency Response and Preparedness County Service Center	Opened and remained operational throughout the outage, supporting an area consortium of police, fire, and other responders. Distributed generators, managed water supplies, and relocated 120 critical patients to hospitals that had backup power.
Road Commission for Oakland County	Prioritized intersections for use of portable generators.
Suburban Mobility Authority for Regional Transportation (SMART)	Maintained operations throughout the first day of the blackout, suspended general service during the second day due to loss of communications equipment, but continued service to priority paratransit customers, and loaned vehicles to area fire departments for use as public cooling stations.

Prior to August 14, the MTA Bridges and Tunnels agency in New York had equipped its systems with full backup generating capacity. Other agencies, however, had not prepared as well. Subsequent to August 14, many agency representatives therefore began purchasing new sources of backup power.

During the blackout, representatives of some agencies were surprised by what was not covered by their backup systems. Two agencies lost power for the card key systems that govern access to their offices. Some agencies had backup power for their computers but none for the air-conditioning units needed to cool that equipment. Some staff mentioned that their generators were centrally, rather than strategically, located. They had trouble deploying the generators because traffic congestion slowed the workers.

In recent years, NYC DOT has upgraded many traffic signals from incandescent lamps to light-emitting diode (LED) displays, which require less power to operate. As a result of the blackout, the agency also is considering adding battery backup to signals at critical intersections.

The transportation officials who were interviewed for the case studies

Planning Actions Taken

- Learned from previous events and adapted plans to incorporate findings
- Developed emergency response plans and held drills
- Established emergency operations centers
- Adopted incident command systems
- Developed cooperative agreements among agencies
- Installed seamless backup power supplies
- Initiated emergency response procedures within minutes of the event

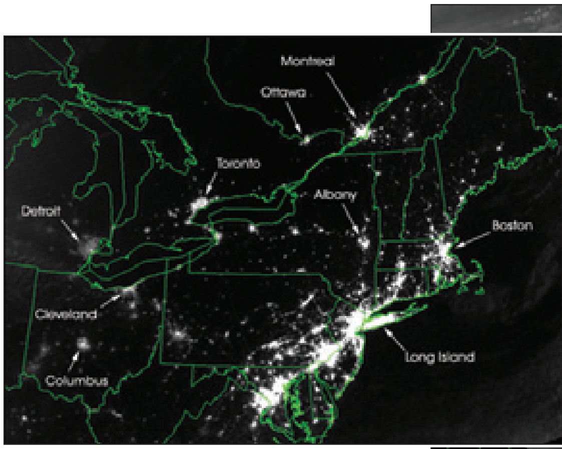
advise periodically reevaluating the need for backup generators, identifying additional means of obtaining backup support, and testing the backup power under a full load. "We are continually running tabletop emergency exercises with communities throughout the State," says Chief Joseph Bober, head of police at New Jersey Transit Corporation (NJ TRANSIT). "It's important for them to know what equipment and services we have to bring to the table, and at the same time, it is important for us as a statewide transportation agency to know what those communities have to bring to the table."

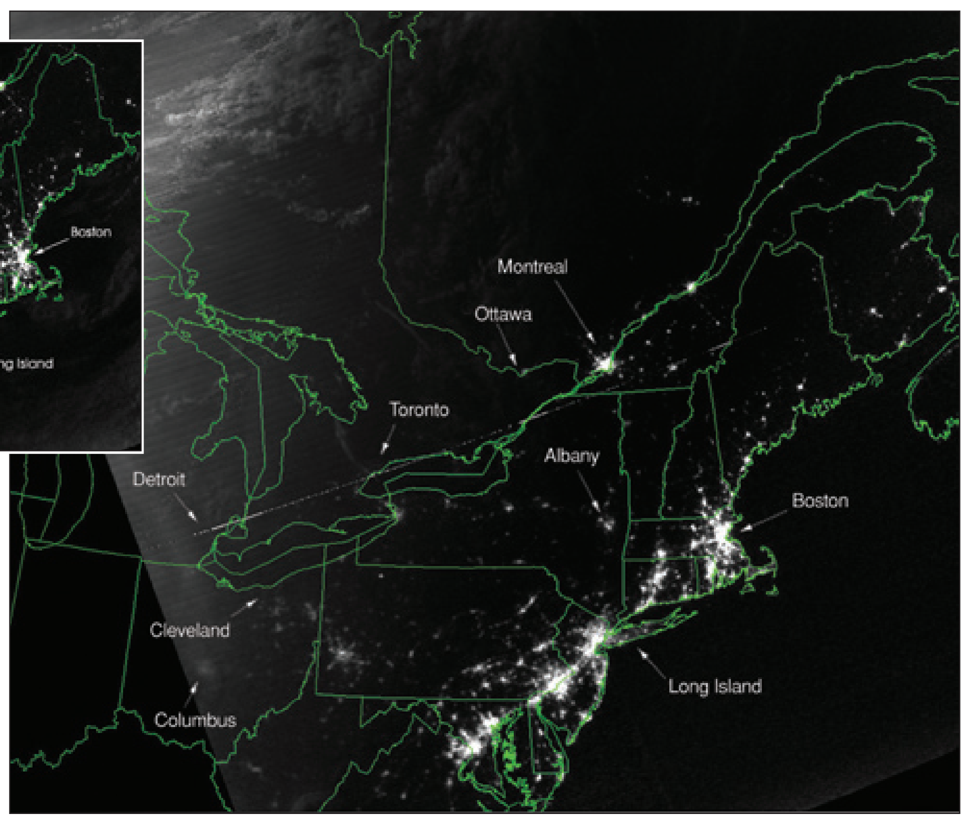
Finally, to maintain a state of readiness, agencies need to conduct frequent drills—the third component of preparation. "We train on a regular basis," says the Detroit-Windsor Tunnel's Belitsky, "both live exercises and tabletops. Each April we close the tunnel on a Sunday morning, and every year our training scenario becomes a little more complex." A tabletop exercise is a training exercise that simulates actions, reactions, policies, and procedures for a specific type of incident, and Belitsky recently participated in one that involved about nine different agencies.

Chief Bober adds, "I can't emphasize the importance of training enough. For example, the drivers who operate NJ TRANSIT's 2,200 buses are trained under the Transit on Patrol (TOP) program to call in crashes, incidents of road rage, or anything suspicious to their dispatcher. The drivers act as another set of eyes and ears."

NJ TRANSIT also provides Community Emergency Response Team training so that employees can assist during emergency incidents. Although they are not to be confused with first responders, the NJ TRANSIT employees can assist when called upon. In addition, NJ TRANSIT trains volunteer employees to serve as "Hub Teams" that are deployed to major transportation hubs during emergencies, where they provide live communications links between NJ TRANSIT and its customers.

Based on lessons learned during the blackout, staff at one agency now will be training in-house employees for jobs normally performed by a contractor. When a generator failed during the blackout, contractor staff members were not available to fix the problem. In-house staff needs to be able to repair and service equipment during an emergency.





These satellite photographs show the affected region 20 hours before the blackout (inset) and 7 hours after the power outage started. *Photos: U.S. Geological Survey.*

Effective planning should include not only planning for the immediate crisis, but also for the recovery. And after the recovery, response and emergency plans should be reviewed for lessons learned. Staff members at Information FOR Motorists (INFORM) noted that, during the recovery, resetting traffic signal controllers was difficult with a limited staff. After the emergency, the agency's staff members assessed their actions, and they now group intersections according to snowplowing routes. The agency will be making laminated sheets of the routes to guide technicians as they reset the signal controllers.

Chief Bober notes that, after the recovery, NJ TRANSIT Executive Director George Warrington took the "aggressive step of personally directing a Trans-Hudson Emergency Transportation Task Force to coordinate interagency responses. It was something that needed to be done, but no one had ever done it. Now we have plans put together no matter what the emergency involves. We've conducted tabletop exercises to make sure our plans work, and we have both sides of the river talking together."

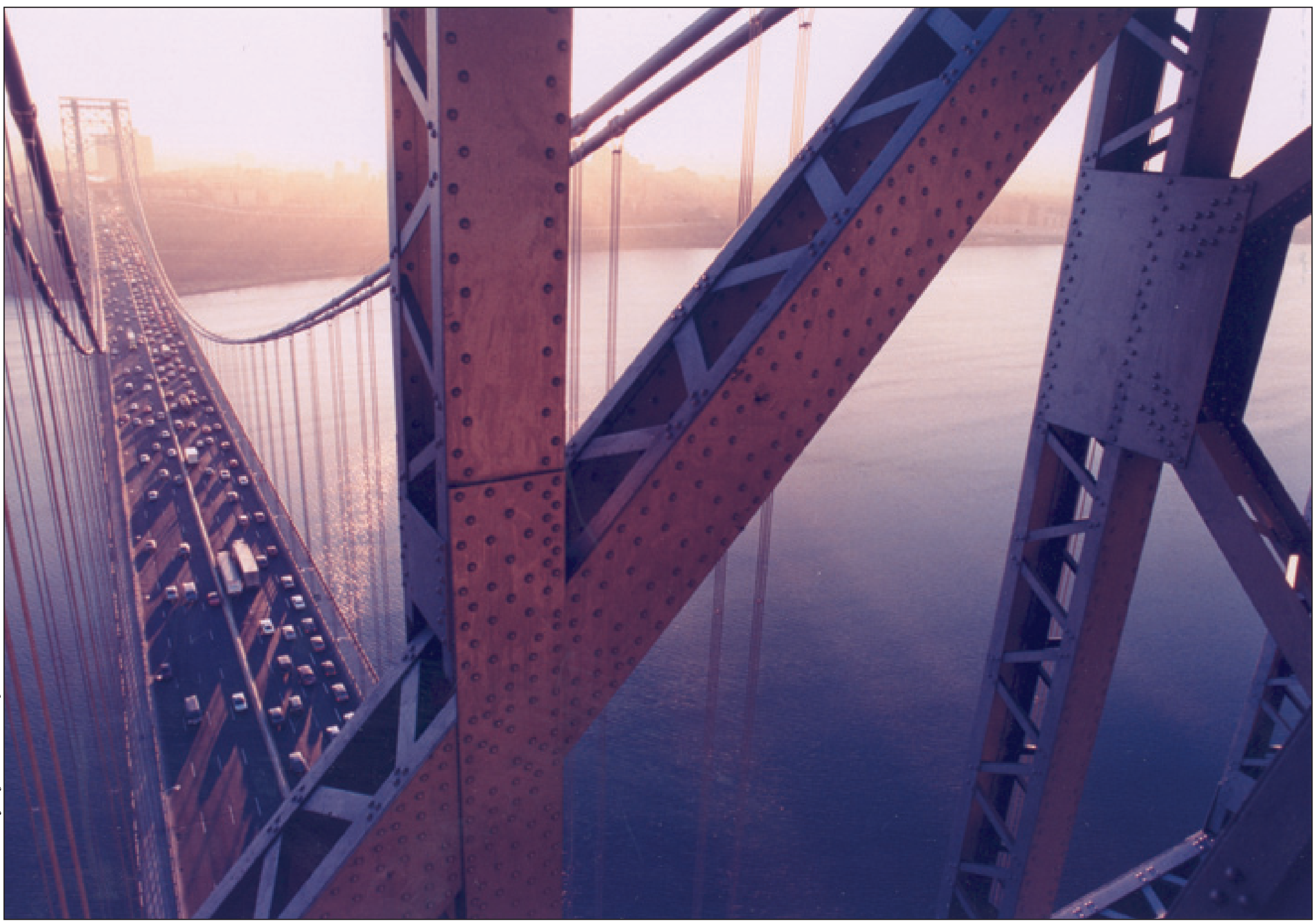
Most of all, plan for all types of emergencies, officials counsel, as crises can come in many different forms. It is true that emergency responses can have a great deal of overlap; several organizations in Detroit mentioned that their snow emergency plans were useful during the blackout. But the more types of events considered under a plan, the more likely an agency will be prepared for whatever happens.

Operating Decisions

Emergency planning enables staff to make day-of-event decisions operate more smoothly. Even for agencies that decided to shut down completely, a preestablished plan made those choices easier. Because a plan was in place, for example, the Detroit-Windsor Tunnel staff was able to make a swift decision to close the tunnel shortly after losing power.

Nevertheless, planning may not prepare an agency for all contingencies, and the operating decision to close the tunnel had ramifications. Executive Vice President Belitsky notes that Canadian nurses staff many U.S. hospitals, and shutting down the tunnel meant they could not get to work. "We've refined some of our procedures now for getting them across the border," he says. Furthermore, operation centers were opened on both sides of the U.S.-Canadian border, but transportation officials were unaware of how to reach each other. "So now we know the phone numbers and even addresses in case we have to go there physically," says Belitsky.

In New York, tunnel managers made several key decisions throughout the blackout. One was to close



Port Authority of NY and NJ

During the power outage on August 14, 2003, the George Washington Bridge continued to operate because it received power from multiple sources. The bridge is seen here from one of its towers.

Operating Actions Taken

- Established priorities as quickly and accurately as possible based on available information
- Sustained operations according to established continuity procedures
- Worked with first responders to provide necessary help
- Empowered field staff to make field decisions
- Implemented established procedures for evacuations when necessary
- Shared resources with other agencies

some traffic lanes within some tunnels. Because the facilities' ventilation systems require an excessive amount of power, managers previously had decided not to connect them to the backup system. Therefore, the tunnel operators had to reduce the number of cars allowed through at any one time to decrease the pollutants. Some bridge and tunnel operators reversed one lane so that there would be three lanes for traffic leaving Manhattan and one for vehicles entering the area.

Agency managers may have to make a number of other difficult operating decisions, such as how to fill staffing needs, how to best serve customers under the circumstances, and whether to continue operations at all. Officials noted the need for a preestablished plan for operating during a communications outage. At agencies that had a plan, field staff members were able to respond to the changing conditions without direct supervision from headquarters. Education, training, and drills may help agency members make better decisions under stressful conditions.

"During the blackout, NJ TRANSIT shuttled commuters from the Port Authority Bus Terminal in Manhattan to the Meadowlands Complex/Giants Stadium, which served as a temporary staging area for New Jersey commuters, who were then shuttled on their normal bus routes to their homes," says Chief Bober. Managers decided on a load-and-go solution to move commuters out of New York City regardless of their final destination, which helped alleviate congestion and confusion.

"For the most part, everyone was together who had to be together to make intelligent decisions," says the

AP/Wide World Photos

Ramin Amiri, a tradesman, directs traffic at an intersection in Toronto, Canada, which also was affected by the blackouts.

chief. "The decisions weren't being made in a vacuum, but rather jointly and in the best interests of the customer."

After the blackout, NJ TRANSIT built an emergency operations center (EOC) that is outfitted with the latest equipment, plus direct lines to the agencies that NJ TRANSIT deals with during emergencies. "The EOC is a think tank and decision tank where everyone sits who decides how we're going to handle the situation," says Chief Bober.

Transit agency representatives add that it is important to set priorities as quickly as possible. Once officials at NYC Transit realized that the blackout would last more than 30 minutes, they initiated established evacuation policies for the subways. Another piece of advice shared by highway and transit agencies: Develop procedures detailing when to restart your system, given that additional power outages, surges, and spikes may suggest waiting for a "quiet time" without surges before starting up.

Agency Coordination

The response to catastrophic events usually requires participation by Federal, State, regional, and local agencies. Coordination among agencies should be ongoing and should be continually reassessed, particularly after a serious incident.

Internally, transportation agencies need coordination among staff, especially for agencies with many different operating entities. As one agency representative mentioned, knowing your colleagues and how to connect them may prove extremely helpful.

Externally, personnel from a transportation agency need to know the functions and capabilities of other transportation agencies. During the blackout, the staff of bridge and tunnel experts that still had functioning cameras verbally relayed existing conditions to the agencies that could no longer obtain video feeds. In addition, preexisting relationships with private carriers to provide substitute and supplemental transportation services were helpful in providing options during the first hours of the blackout.

As an example of what can go wrong, one agency official in Detroit noted that long-standing rivalry with another agency made it almost impossible for the two to collaborate in even a basic way, although their cooperation might have eased congestion during the blackout. In another example of the problems that can occur if multiagency coordination is lacking, officials from multiple agencies were required to give permission for the establishment of an emergency response center, greatly slowing its opening. In other cases, established chains of command among agencies proved to be cumbersome and inefficient, also reducing response time.

Transportation agency staff members need to know the capabilities of nontransportation agencies as well and have strong working relationships with law enforcement, public utilities, public health officials, fire departments, and other emergency responders. Because NYC Transit had a preexisting relationship with the electricity provider, Con Edison, the transit agency was able to obtain accurate information on the extent and possible duration of the blackout, enabling the

Coordinating Actions Taken

- Cultivated relationships during normal times to ease cooperation during an event
- Linked the various arms of an organization for better internal coordination
- Installed dedicated voice or data links to relevant agencies
- Practiced an incident command system
- Established mutual aid agreements
- Worked closely with countywide and statewide emergency operations centers
- Provided information to the media as quickly as possible
- After the event, collectively reviewed performance and cooperation

Port Authority of NY and NJ

Within 10 minutes of the start of the blackout in New York City, transit managers began evacuating passengers from subways like this one.

Technology Actions Taken

- Employed multiple forms of ITS to broadcast information to travelers
- Used closed circuit television images to assess traffic conditions and modify operations accordingly
- Used real-time ITS traffic data to design detours and facilitate evacuation
- Employed ITS to alert motorists outside the affected area of problems ahead
- Utilized ITS to link traffic management centers to share travel conditions information among centers

agency to begin evacuating the subways quickly.

The New York area and Great Lakes region case studies revealed that coordination between agencies during emergencies can exist on two levels, both formally among institutions and informally between individuals. As a formal example, the Transportation Operations Coordinating Committee (TRANSCOM), funded by 18 agencies in the Connecticut, New Jersey, and New York metropolitan area, serves as an information exchange network for incidents affecting traffic and transit conditions in that region. The I–95 Corridor Coalition, which includes representatives from transportation agencies in States from Maine to Florida, provides funding to contract TRANSCOM's services in this role when incidents outside the tristate area have impacts on the corridor. "This is when TRANSCOM puts on its I–95 hat," says Marygrace Parker, operations coordinator for the coalition and a former traffic manager and police officer, "and does the same services outside its region."

Both TRANSCOM and NJ TRANSIT have toll-free numbers that staffs from the various agencies can call so that they can conduct conference calls. In addition, TRANSCOM had previously hired a contractor to provide a faxing service physically located outside the region.

Sometimes agencies even agree to share office space. The Connecticut DOT offers space in its building for FHWA Connecticut Division Office staff in the event that the FHWA facility is rendered inoperable. In a similar effort, since the blackout, some of the major transportation agencies in the New York region are linked by dedicated telephone landlines into one another's offices and into those of their contract carriers.

Informal individual relationships may be even more important. Relationships established and nurtured during normal times can pay enormous dividends during emergencies. The Port Authority of New York and New Jersey was able to borrow large generators mounted on trailers from the Port Authority of Baltimore and of Philadelphia. Staff attributed this action to the fact that a district manager had developed relationships with transportation officials in those cities after September 11. The manager knew whom to call.

"If you know each others' resources and understand each others' needs," says Parker, "you start to develop a comfort level. Even if you have no way to communicate during an emergency like the blackout, the operator in Virginia can still anticipate your needs based on the last 10 times you've worked together and will start using his equipment to assist. In this case, Virginia DOT utilized VMS equipment to post messages regarding transportation impacts in the Northeast region."

Role of Advanced Technology

Over the last decade, ITS technology has played an increasingly significant role in helping managers operate their systems during both normal times and emergencies. Advanced technology is vulnerable to the loss of power, however, at any point along the information chain—from equipment in the field to the control centers.

Agencies in New York City and Detroit reported that the ITS equipment that stopped working included traffic signals and signal controllers, variable message signs, closed circuit television cameras, global positioning systems, and some automatic vehicle location systems. Other technologies also were unreliable, such


MITS Center

This depressed freeway and pumping station is located on the northbound side of I–75 in Detroit. A heavy rain flooded several sections of depressed freeway during the power outage because the pumps had no power.

as cellular telephones, cordless telephones, some pagers, some landline telephone systems (once phone company backup battery power expired), some fuel pump computers, two-way portable radios (due to nonfunctioning repeaters), some point-to-point radios in buses, some computer-aided dispatch systems, and climate control and lights in some traffic information centers.

Steven Fern, manager of electronics and communications at SMART in Detroit, says, "The local phone carrier did fine in keeping analog services up and running, just as they have been doing since my grandfather's day. The digital service didn't die immediately, but did 12 to 14 hours into the event, as the in-circuit devices between the central phone office and customers' offices lost power."

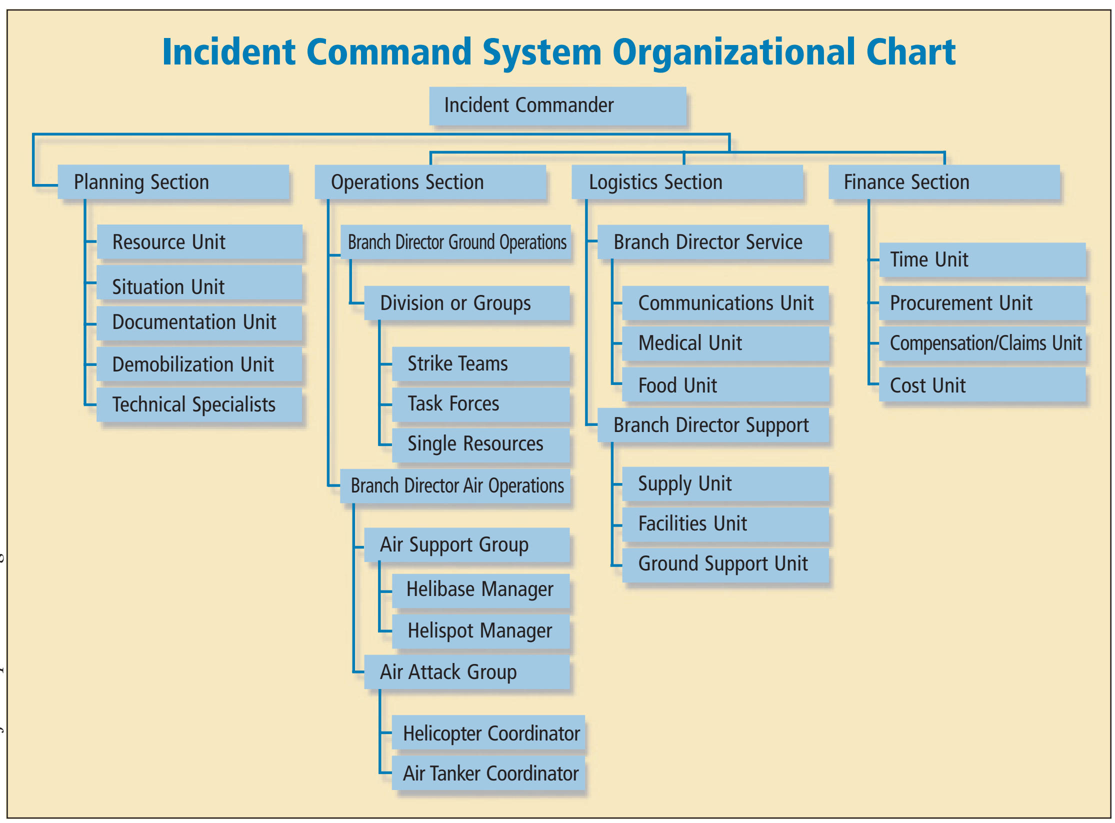
His colleague, SMART Director Ristau, adds, "Phone service was somewhat sketchy on Friday. We did try to keep our small bus service going, especially for kidney dialysis patients. Because we couldn't reach some hospitals by phone, however, we reverted to a 'pony express' kind of system where we sent drivers out physically to the hospitals to see if they were open and doing dialysis."

An important lesson learned is the need to identify those components of the ITS network that should be capable of operating during an emergency. Allocating capital and operating funds to maintain backup power in those parts of the system is imperative. The root causes of a power loss—storm, technological failure, violence, or sabotage—are irrelevant. All blackouts present the same challenges, and the ITS systems should be designed to function no matter what the specifics of the situation are.

Other lessons learned about advanced technology:

- *Intersections:* The ability to maintain the signal system is key, unlike with freeways, which will operate reasonably well without power. A response plan for priority signals should be based on an evaluation of intersection safety, sight distance, and traffic volumes. Several agencies are now examining the costs of providing backup power supplies to ITS field equipment along key corridors and intersections. Emergency power for the computers controlling the centralized traffic signals—those run from a traffic management center—should be provided by multiple backup batteries.
- *Communications:* "Old" technologies, such as landline telephones and battery-operated radios, become very important when a crisis is widespread. Officials recommend maintaining some older technology, which may be less susceptible to power outages, in the traffic management center. As for backup power, even quadruple redundancy is not foolproof.
- *Operations:* Prioritize where backup generators are deployed. To keep emergency vehicles on the road, backup power is essential at fueling facilities. When an outside contractor performs generator maintenance, in-house staff should retain maintenance capability for emergency situations. Regular generator maintenance should be scheduled as standard operating procedure. The ability to maintain toll collection using backup power allows large volumes of traffic to be handled at toll booths with few customers aware of the blackout until they leave the tollway.

SMART's Fern adds that the first lesson learned was to perform system tests. "But any kind of test where you're simulating a failure is inherently an intrusive thing to do," he says. "It gets in the way of business, but there's no other way to know whether your equipment is going to work. We do a WAN [wide area network] failover test every 4 to 6 weeks. We unplug a fiber, actually pull the plug, making it happen exactly the way it would in the real world. It's like security. You can have



Institute of Transportation Engineers and FHWA

Recommended organizational structure for an incident command system.

Communications Actions Taken

- Adopted new forms of communications as new technology was developed and refined
- Used multiple communications technologies to ensure that at least one form of communications would be working
- Sometimes relied on old technology when newer technology failed
- Executed established plans for communications outages when necessary
- Employed government-sponsored priority communications systems such as the Government Emergency Telecommunications Service (GETS) and Wireless Priority Service (WPS)

as much as you want to pay for, but there will be inconvenience."

Although a large percentage of ITS equipment was not fully functioning within the affected areas, agencies outside the blackout area were able to use ITS technologies to alert motorists. The Maryland DOT, PennDOT, New Jersey DOT, and New Jersey Turnpike, among others, all used their ITS technologies to broadcast alerts using variable message signs, highway advisory radio, and Web-based messages. For example, the Maryland DOT placed messages on its I–95 northbound signs, "Massive power outage in NY—Avoid area—Use alternate routes."

Technical Communications

The ability to communicate, internally and externally, is the most critical technological capability required in an emergency, according to the case study findings. Fast communication is crucial to stem anxiety, transmit instructions, and begin the process of recovery. Reliable communications technology is particularly important for transportation agencies, since many employees may be working in the field. Agency staff should drill specifically for the failure of communications equipment.

During the 2003 blackout, transportation officials learned the importance of low-tech solutions. The plain old telephone system proved to be the most reliable form of communications technology during the blackout, because cell phones, cell phone towers, radio repeaters, and Internet connections failed due to the loss of electrical power and limited backup capabilities. Agencies that had newer central telephone systems experienced more problems than agencies with older systems. To communicate, agency representatives used a combination of facsimile machines, pagers, toll-free numbers and conference call lines, older radio systems, and previously installed dedicated landlines.

Ohio DOT found that agency managers' landlines worked, but many were nevertheless unaware that they were receiving a call because the electronic ringers on their telephones were inoperable. Ohio DOT's Huebner has an old-fashioned bell ringer on one of his telephones at home and heard that one.

He adds, "Our two-way pagers helped us communicate the most. Our public information officers have pagers, and after about 4 hours, the cell phones came back on, so they communicated with the media mostly by cell." Huebner notes that Ohio DOT benefited from the helicopters that the local news channels had in the air, reporting on darkened intersections and traffic jams.

Steven Coleman, public affairs officer with the Port Authority of New York and New Jersey, got the word out within the first hour by typing a summary of traffic activity on pagers for executives to review and then using cell phones to call the Associated Press, which then distributed the information to other media. "Then all of our staff was given a police escort across to New Jersey to the emergency command center," Coleman says, "where we have generators and could do much broader outreach. We staffed that operation throughout Thursday night and then all day Friday and Friday night."

Agency officials need to understand how to provide the media and the public with accurate and timely information. Preestablished relationships with media outlets can help an agency better alert its customers about available options. NJ TRANSIT staff is devising a training program for members of the media to enable them to identify the responsibilities of the various transportation agencies in the region and the facilities that those agencies manage or operate. Part of this training will involve developing a list of agency points of contact for the media plus a list of media contacts for the agencies.

Corel Corporation

New Yorkers spent many hours trying to get home on foot or by ferry boat, like this Staten Island Ferry.

Since the 2003 blackout, the Ohio DOT has developed a new process flow for situations where communications go down. "Managers are to report to work," says Huebner, "and notify the district office through their radios on how many crews they've brought in. And we will notify the media, even if we have to drive there, and the local media have agreed to broadcast public service announcements such as 'ODOT shift 1 is to report.'"

The Trans-Hudson Emergency Transportation Task Force identified communications technology as the leading problem of the blackout. The task force's findings were that most agencies thought they had more communications redundancy than they did, failed to understand the frailty of their technology, and thought that they had better backup power.

The inability to communicate reliably during the blackout was also the most consistent finding in the Great Lakes region. The more communications options that agency personnel have at their disposal, the better. Although many worked at certain times—fax, e-mail, cell phone, pagers and text messaging, two-way radio—none of the technologies worked all the time.

Recommendations are to establish direct lines of communication with nontransportation agencies and media outlets, establish a NonComm plan, and strengthen communications among transportation agencies by preestablishing a protocol for communication—telephone, fax, or Internet—with particular attention paid to ensuring redundancy in those systems.

Another recommendation is to explore the option of joining the Government Emergency Telecommunications Service (GETS) and Wireless Priority Service (WPS), two federally sponsored priority communications systems that provide preapproved users with priority routing of landline (GETS) and wireless (WPS) calls during emergencies, even during periods of peak demand. Users include Federal, State, and local government agencies, plus private companies and organizations with responsibility for national security or emergency preparedness. Transportation agencies are granted a fourth-level priority within GETS and WPS, as are other public utility agencies. For more information, see http://gets.ncs.gov/ and http://wps.ncs.gov.

Redundancy Actions Taken

- Expended resources to provide for redundancy in personnel and infrastructure
- Bolstered alternative transportation services to help replace unavailable modes, such as providing extra buses, trains, or boats
- Used redundant traffic corridors to establish detour routes to circumvent unavailable infrastructure
- Trained personnel to be able to fill in for key players who may be unavailable
- Trained and empowered the decentralized field staff to make independent decisions
- Used multiple technologies to communicate with staff, other agencies, and the public
- Installed backup power supplies for critical equipment and facilities
- Built mobile command centers to supplement fixed control centers
- Inventoried existing supplies and equipment
- Established outside sources for additional supplies on short notice

System Redundancy and Resiliency

The level of appropriate redundancy—the ability to activate backup systems for expertise, equipment, vehicles, communications, and technology—varies from agency to agency. Redundancy needs to be reevaluated constantly based on the results of emergency response training and experiences during actual emergencies. Some large-scale events, such as the 2003 blackout, may always exceed the amount of available redundancy. Given financial and other constraints, managers

Port Authority of NY and NJ

During the blackout, NJ TRANSIT shuttled commuters from the Port Authority Bus Terminal (shown here) in Manhattan to the Meadowlands Complex/Giants Stadium in East Rutherford, NJ, which served as a temporary staging area.

Ray Engel, NYS Thruway

Variable message signs, such as this one, can provide traffic information during emergencies. During the blackout, signs along I–95 advised motorists outside the affected areas to use alternate routes.

must assume the most likely types of potential emergencies when planning for redundancy.

From the experience of the blackout, clearly a source of backup power is the most important investment an agency can make. Most other systems—communications, safety, and security—will operate so long as backup power is available and sufficient. Emergency power must be tested and maintained, and must be connected to the appropriate systems.

Communications is another area where redundancy can be important. Sometimes double and even triple forms of communications alternatives are not enough. Several areas of New York City experienced a loss of landline communications because three of one phone company's central offices experienced outages. Cell phones and radio networks failed since repeaters either were not equipped with backup power or had batteries that ran out after approximately 4 hours. Also, call volumes overwhelmed the phone systems. Even the city's 911 system failed due to the heavy call volume.

Many times, the need for backup power is not obvious until an agency tries to function without it and a gap is identified. Air-conditioning consumes a large amount of power to cool a building, so it is often not included in the backup power system. But critical technologies such as computers need to be cooled so that they do not overheat.

After August 14, agencies noted some of the items that were left off of the backup power supply but should have been considered for possible inclusion:

- Electronic keyed door entry systems
- Network-based telephone systems
- Fueling systems for public and private vehicles
- Sump pumps for tunnels or roadway sections that are prone to flooding
- Spare outlets for small appliances (such as battery rechargers)
- Air-conditioning for equipment rooms
- Internet servers hosting e-mail systems
- Radio communications systems
- Building security systems

The 2003 blackout served to expand the definition of redundancy. The blackout highlighted the possible necessity of having backup centers located physically outside of the affected region and "virtual operations centers." By having the capacity to connect a computer into a virtual network, an agency can run its operations from a secondary site or even from the homes of key personnel. Redundant facilities are less likely to be affected by the same events as the primary operations site if they are located far enough away.

At a minimum, planners should consider designing redundancy in several areas: agency personnel, communications, utilities, control centers, and equipment and supplies. They must also be aware of the redundancy in the regional transportation system. Agencies should perform inventories of their own internal assets as well as establish contact with other agencies where additional assets could be requested. In many circumstances, these strategies are cost-effective. But if an event covers a wide geographic area, as the 2003 blackout did, parties that have agreed to assist one another

Detroit & Canada Tunnel Corporation

The Detroit-Windsor Tunnel across the U.S.-Canadian border closed down, despite four separate and independent power feeds.

Many of the tunnels into Manhattan, such as the Lincoln Tunnel shown here, were immediately closed or access to them was restricted.

Port Authority of NY and NJ

may be unable to do so because they need to address their own set of problems or are spread too thin.

Also, test and maintain backup systems. A number of agencies had invested in generators but found that they malfunctioned, required repairs, or even caught on fire when called upon for extended use during the 2003 blackout. Other agencies reported that they test their generators by switching to backup power and simulating a load on their backup system on a weekly or monthly basis for 12- or 24-hour stints. They also schedule routine preventative maintenance.

Assessing the needs posed by an extended loss of the primary system versus a temporary interruption is crucial. Equipment such as air-conditioning and fuel pumps became important as the blackout continued. One lesson learned in this category is that basic facilities should be provided for staff members who may have to work multiple shifts during a prolonged emergency.

But building redundancy into the system can be expensive and seen as "wasteful spending" in ordinary times. It is always cheaper to have only one of a particular type of infrastructure, but failure of that system can hamper response and recovery efforts significantly.

"One of the things we learned is that backup generators and uninterrupted power supplies are worth the money," says Richard W. Morgan, director of information systems at the Ohio Turnpike Commission. "The sign of that is that the power outage did not inhibit anyone from being able to enter the toll road, and investors didn't lose any money."

Because the Ohio Turnpike's service plazas have backup generators, they were able to continue dispensing fuel. At one point, because most gas stations were unable to pump without electricity, the Toledo radio and television stations informed Detroit motorists that they could obtain gasoline at the turnpike's service plazas. "People could come to the turnpike and get gas," says Morgan, "and they did."

Much of the turnpike's backup equipment has been in place for 20 years. Morgan adds that building in redundancy "as you go along makes it easier to intelligently improvise on the fly for something that hasn't been preplanned."

Wake-Up Call

"At the end of the day," says the I–95 Corridor Coalition's Marygrace Parker, "whether it's a hurricane, a blackout, or a terrorist event, the way you manage traffic incidents is essentially the same. There's no incident that occurs on any scale that doesn't have traffic impacts. And most important is having the institutional and personal relations in place, nurturing and sustaining them."

In other words, institutional coordination—and emergency response plans, effective operating decisions, advanced technology, technical communications, and system redundancy—all are vital components of preparation. Most important to remember is that preparation is never complete. It is an ongoing process. The 2003 blackout is just another in a long series of wake-up calls about the need to prepare for the unexpected.

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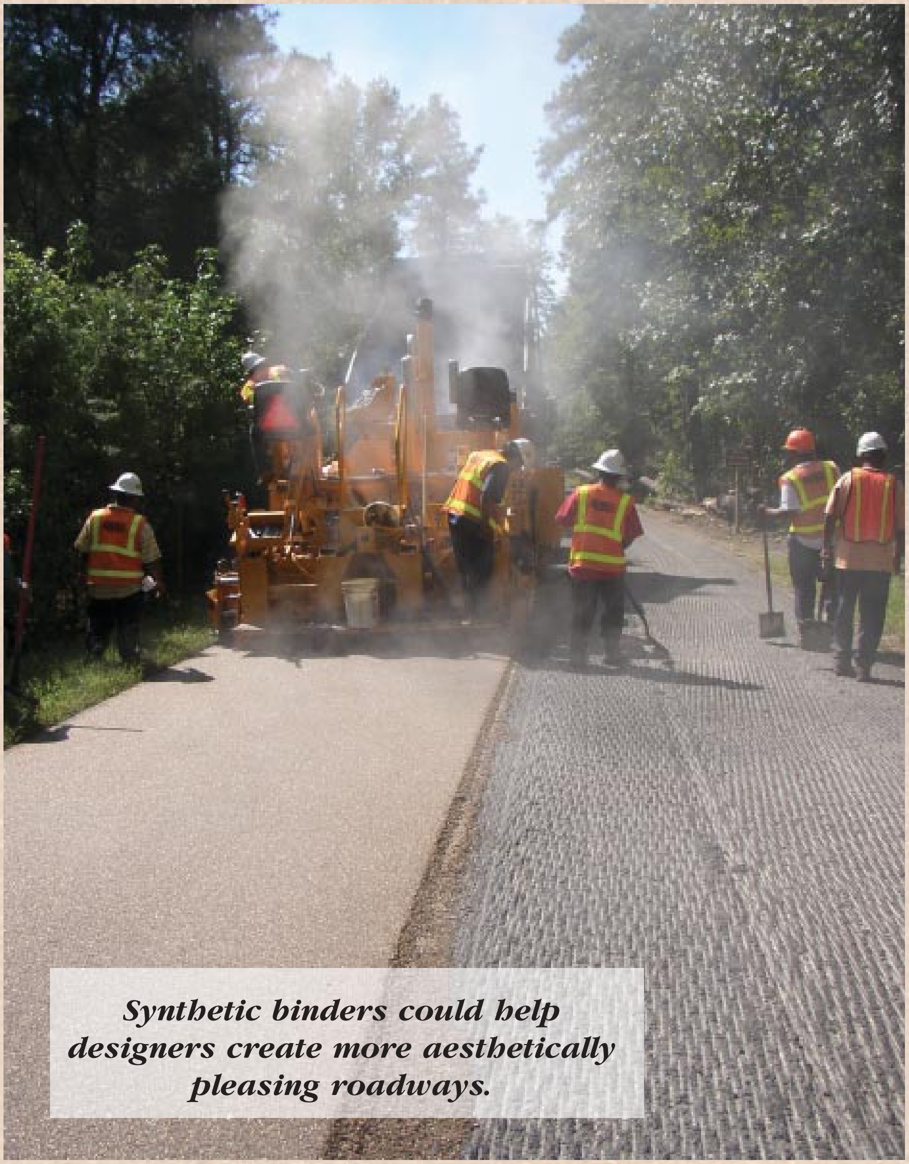
For more information on the FHWA Emergency Transportation Operations Program, see www.ops.fhwa.dot.gov/opssecurity or contact Vince Pearce at 202–366–1548 or vince.pearce@fhwa.dot.gov.

Rustic Pavements

by Michael P. Dallaire and Scott A. Saunders



Synthetic binders could help designers create more aesthetically pleasing roadways.

Selecting a pavement color for a highway project may someday be as easy as shopping for paint. With the growing interest in context-sensitive solutions for roadways and transportation facilities, Federal and State agencies are looking for more and more opportunities to create transportation systems that respect and protect local environmental, cultural, and historic resources.

When developing pavement mixes, designers traditionally focus on choosing materials that meet stringent standards for quality, durability, smoothness, and cost. "Typically we don't worry about color," says Laurin Lineman, technical services engineer with the Eastern Federal Lands Highway Division (EFLHD) of the Federal Highway Administration (FHWA). "We use a local source aggregate that does the job cost effectively." Except for nuances particular to the chosen aggregate, the range of colors for most asphalt and concrete pavements spans from black to various shades of gray.

But recently FHWA began performance testing on a new synthetic binder that could add "color" to the list of key criteria that pavement engineers consider as they develop their designs. Researchers at the Turner-Fairbank Highway Research Center in McLean, VA, are in the process of studying a clear polymer binder (or resin) to assess its performance characteristics. When combined with an architecturally aesthetic aggregate (gravel), the binder could help designers create "rustic pavements" that look like old dirt roads or historic pavements but have the structural capacity necessary to carry modern traffic loads. Unlike the liquid binder in hot-mix asphalt, which lends a black color to whatever aggregate it covers, a more translucent, synthetic binder allows the natural color of the aggregate to show through.

(Above) Workers are applying rustic pavement to Picnic Road at Richmond National Battlefield Park.

"Rustic pavement represents one approach to satisfying a number of issues for our partner agencies," Lineman says, "including aesthetics, preservation of historic character, and lying gently on the land." EFLHD, which provides highway assistance to the U.S. Department of Agriculture's Forest Service and the U.S. Department of the Interior's National Park Service (NPS) and U.S. Fish and Wildlife Service, requested the work to support its search for context-sensitive solutions. "Our goal is to add another 'tool' to the context-sensitive solutions toolbox," says Lineman.

EFLHD recently completed a successful field test at the Richmond National Battlefield Park in Virginia. With ongoing testing at Turner-Fairbank and a high-profile project planned for a section of Pennsylvania Avenue in front of the White House in Washington, DC, rustic pavements are poised to roll out in new applications across the United States.

Coloring Options

According to Lou Benvenuti, director of marketing, strategy, and development with the Neville Chemical Company, which developed the material, synthetic binders have been around for several decades. "We did many jobs using a similar binder back in the 1960s and early 1970s," he says. "We initiated work to improve upon the original invention and characterized the binder according to the testing protocols developed from the Strategic Highway Research Program."

The synthetic binder offers two distinct ways to add color to a pavement. In the first, the binder replaces the black liquid binder in hot-mix asphalt, so the natural color of the aggregate becomes the dominant pavement color. A second application involves adding a pigment to the mixer during hot-mix production to create red, yellow, blue, green, white, or other colored pavements.

In Europe, pavement designers use synthetic binders with pigments to delineate intersections, bicycle paths, historic landmarks, busways, and roundabouts. "Adding a pigment to the pavement offers safety benefits, as well, from improved visibility," Benvenuti adds.

Testing at Turner-Fairbank

To assess the performance of the rustic pavement concept, researchers at Turner-Fairbank are conducting a series of laboratory tests to study properties such as durability, weathering, moisture susceptibility, and resistance to rutting.

According to Tom Harman, pavement materials and construction team leader at Turner-Fairbank, his team is comparing the performance of various rustic pavement mixes to a standard hot-mix asphalt that is known to perform well. "Basically we are subjecting samples of both materials to a series of extreme torture tests," he says. "The question we are trying to answer is, 'Will rustic pavement provide equal or better performance when compared with standard hot-mix asphalt?'"

The tests include laboratory rut testing using the Hamburg Wheel-Tracking Device and the Superpave™ shear tester. "More important," Harman says, "we're looking at the aging susceptibility of the clear binder using a weatherometer and assessing the material's infrared spectrum. This tells us the aging properties of the clear binder. We need to make sure the binder will not oxidize too quickly and become brittle."

Once the testing of the clear binder with standard aggregates is complete, Harman and his team will repeat the experiments using the architectural aggregates planned for use on a project on Pennsylvania Avenue in Washington, DC.

The Richmond Site

The first field application of rustic pavement was at the Richmond National Battlefield Park near Richmond, VA. Established in 1936, the park protects 309 hectares (763 acres) of historic ground, commemorating 11 different sites associated with the Civil War.

When a section of Picnic Road in the park began to fail, especially in the wheel path, engineers from EFLHD suggested replacing the existing chip seal with a rustic pavement. The National Park Service agreed, and in September 2003, EFLHD paved a 1.6-kilometer (1-mile) strip of roadway and a parking area using the synthetic binder and brown and tan aggregates to achieve a brown-colored pavement.

"We had a light-brown pavement to start with," says Dan Hodgson, facility manager at the park. "The pavement was placed many years ago and had a brownish aggregate. When we couldn't find a good replacement for the aggregate, we started looking at other options. Our goal was to find a pavement that would look like a dirt road."

According to EFLHD's Lineman, gravel roads do not hold up well to traffic and are maintenance intensive. "We needed to use a pavement," he says, "and the rustic pavement option enabled the park to have a more aesthetically pleasing road that, from the engineering standpoint, can carry traffic."

Paving Operations

No special equipment is necessary to place rustic pavement. "You transport the materials in the same trucks, run the materials through the equipment just like you do for hot-mix pavement, and compact and roll the same way," says Thomas Scott, construction operations engineer with EFLHD. "As with typical asphalt pavements, the pavement crew makes the standard adjustments for the mix-specific combination of binder and aggregate. Once it cools, the rustic pavement acts just like a regular pavement."

The Richmond job involved placing approximately 450 metric tons (500 tons) of hot-mix synthetic binder concrete pavement on the parking lot and a section of roadway. EFLHD specified two mix formulas; one was 9.5 millimeters (0.4 inch) and the other 12.5 millimeters (0.5 inch). The project called for two sources of crushed, coarse aggregate.

The finished pavement on the parking lot at Richmond National Battlefield Park. Clean equipment is necessary to avoid creating the black streaks shown here.

In preparation for the high-profile application of rustic pavement in front of the White House, FHWA conducted a pilot project in scenic Rock Creek Park in Washington, DC (shown here). The project not only tested the proposed aggregate and binder combination but also enabled the contractor to perfect its processes working with the materials.

The contractor paved the parking lot using the 12.5 millimeter (mm) mix, which contained a darker brown aggregate. After three passes with a steel drum roller in vibratory mode and one pass in the static mode, the contractor achieved an in-place density of 92 percent or greater. Compaction occurred immediately after laydown at temperatures near 143 degrees Celsius (290 degrees Fahrenheit). The contractor used a release agent on the steel drums to prevent pickup of the mat during compaction.

Paving on Picnic Road featured the 9.5 mm mix and a lighter, tan-colored aggregate. The contractor needed to hold off on compaction until the mat temperature dropped below 110°C (230°F) because the freshly laid mat of 9.5 mm mix was tearing and picking up in patches when the compaction roller followed closely behind the paver. To avoid tearing, workers in the field need to determine the appropriate temperature for compaction based on the characteristics of the mix.

Completed pavement on Picnic Road at Richmond National Battlefield Park, showing color differentiation, presumably a pigmentation caused by a concentration of fine material in a later batch of aggregate.

Results from the Richmond Test

Based on the Richmond project, researchers learned a number of lessons about how to improve future applications of rustic pavement. Most important, with the new goal of producing an aesthetically pleasing color on the final product, the team realized the need for even tighter quality control measures. For example, a portion of the second travel lane on Picnic Road was darker in color than the first lane. According to Scott, the most probable cause was an increase in the amount of fine material, which acted as a pigment to cause the color change. "We're not used to watching out for color during a paving operation, so this is something we'll have to be more conscious of on future applications," he says.

Similarly, the field test highlighted the need for attention to smaller details, such as the tack coat and cleanliness of tools and equipment. The tack coat, for example, which helps bind the new pavement to the old, is black. "Usually that's not an issue because you're placing black on black," says Nelson Clark, project engineer for EFLHD, "But when workers got the tack coat on their shoes or on the equipment, they tracked it back onto the fresh pavement." To avoid this problem in the future, the binder manufacturer is in the process of developing a synthetic tack coat to match the binder color.

Having clean tools and equipment also is essential. "If the equipment still has leftover asphalt in it from the previous job, black streaks will show up in the new pavement," Clark says.

To date, the NPS staff at Richmond National Battlefield Park has been pleased with the performance of the pavement. "The road looks great," Hodgson says. "We've received a number of positive comments from the park's neighbors who live along the border of the park and drive on the road every day."

In fact, Hodgson adds, the park plans to continue using the rustic pavement application when it repaves two entrances and parking lots later this year. "To me, the rustic pavement appears to be a better product than regular asphalt," he says. "We've had trucks and cars on it, and it looks like the rollers just came off it."

A New Look for Pennsylvania Avenue

Building on the success in Richmond, the National Capital Planning Commission and FHWA are planning to use rustic pavement on a restoration project on a section of Pennsylvania Avenue between 15th and 17th Streets in front of the White House in Washington, DC. The project involves creating a new pedestrian plaza that will improve access for the public, provide generous open space, and enhance views of the White House and other landmarks in the Nation's Capital. Other components include granite sidewalks and new site furnishings such as granite benches, streetlamp installations, and landscaping.

"The crux of the project is determining how to transform a roadway

This artist's rendering shows how the rustic pavement will look in the context of the Pennsylvania Avenue project in Washington, DC.

into something that has a different identity," says Gullivar Shepard, a senior associate at Michael Van Valkenburgh Associates, the landscape architects working on the project. "The road is closed to vehicular traffic, but still it needs to meet the standards for a traffic-ready roadway," he says.

To respect the historic context, the landscape architect wanted to have a warm-colored, granular surface for the roadway area. "Our original concept for the roadway material in front of the White House was to create a landscape-material connection between Lafayette Park and the White House grounds to make the area more park-like," Shepard says.

But this presented several problems: loose granular pavement would be difficult to maintain, it would represent a security concern in front of the White House, and functionally it would not carry traffic as well. Says Shepard, "We quickly learned that the soft paving system we proposed in our competition entry—decomposed granite—would not work with vehicles such as the presidential limousine, which has the weight of a small tank on four small wheels—it would be like high heels in grass."

The other avenue of exploration was a clear synthetic binder, suggested by FHWA. "In redefining the basic components of asphalt—a binder and stone aggregate—we were presented with the opportunity to elevate the aesthetic quality of the pavement system," Shepard says. The selected paving materials will accommodate pedestrians, skaters, cyclists, and horses, and withstand the loading requirements of delivery vehicles, emergency equipment, motorcades, and inaugural parade traffic.

In August 2004, before beginning work on the Pennsylvania Avenue project, FHWA researchers installed a test strip on another NPS site in Rock Creek Park in Washington, DC, using the synthetic binder and chosen aggregates. The purpose of the test was to help the contractor gain experience handling the materials and matching the colors from load to load.

Construction of the Pennsylvania Avenue project is scheduled for completion by October 2004, just in time for the presidential inauguration in January 2005.

Weighing the Costs

Because synthetic binders are a new product on the market, they do cost more. According to Lineman, the binder itself costs seven or eight times the cost for a standard asphalt binder. "Because of the cost, rustic pavements are only an option for selected applications where the historical and cultural significance justifies the expense," he says. "And you wouldn't do a base course, only a surface course."

Using local materials can help keep the costs down. In Richmond, EFLHD and NPS used brown gravel from a local source, keeping transportation costs to a minimum. With the Pennsylvania Avenue job, however, the landscape architect selected three different aggregates from Maine, South Dakota, and Texas, which drove up the costs.

State departments of transportation and municipalities might consider using rustic pavements selectively for projects in historic districts or for bike paths or trails. "The Richmond project is not that well known," says Gary Brown, technology coordinator for EFLHD, "but once Pennsylvania Avenue is finished, we expect to have more people inquiring about the technology."

A Bright Future?

For most highway projects, designers are concerned with selecting paving materials that will handle traffic loading and fit the budget. But the growing interest in context-sensitive solutions for transportation facilities opens up new opportunities for product innovations like synthetic binders that offer functionality and aesthetic benefits.

"Synthetic binders are one approach, but FHWA continues to work with other partners and manufacturers to identify and test other surface treatments," Lineman says. "The goal is to come up with cost-effective, aesthetically pleasing alternatives that meet the requirements for skid resistance, durability, and traffic loading."

Michael P. Dallaire is a materials engineer at EFLHD. He has more than 18 years of civil and materials engineering experience focused on the performance and durability properties of constructed systems, and materials quality control and assurance. Dallaire has a B.S. in civil engineering and an M.S. in civil engineering, both from the University of New Hampshire. He is registered as a professional engineer in New Hampshire.

Scott A. Saunders is the division materials engineer at EFLHD. He has more than 10 years experience in geotechnical engineering, pavement design, and materials quality control and assurance. Saunders has a B.S. in civil engineering and an M.S. in geotechnical engineering, both received from Virginia Polytechnic Institute and State University. He is registered as a professional engineer in Virginia.

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I–95 SHUTDOWN—

Coordinating Transportation and Emergency Response

Emergency planning, unified command, and communication are key to managing a high-profile crash on I–95 near Baltimore, MD.

by David Buck, Breck Jeffers, and Alvin Marquess

Peter Hammond

Two firefighters work to control the flames on a tractor trailer that was caught in the explosion of a fuel tanker that crashed on I–95 south of Baltimore, MD, in January 2004.

According to the U.S. Census Bureau, 23 percent of the U.S. population lives in the I–95 corridor States between Virginia and Maine, and the Maryland Transportation Authority (MdTA) estimates that about 200,000 vehicles travel the road daily in Maryland. The interstate is the main link between Baltimore and the Washington, DC, metropolitan area, including northern Virginia and Maryland, making it a critical artery for north-south traffic and freight flow on the East Coast.

At 2:45 p.m. on Tuesday, January 13, 2004, a fuel tanker traveling south on Maryland's I–895 (the Harbor Tunnel Thruway) plunged over the New Jersey barrier-shaped concrete bridge rail on an overpass and landed on the northbound lanes of I–95 just south of Baltimore. When the tank truck's trailer—a cylinder filled with gasoline—crashed over the bridge's concrete barrier, it pulled the cab down with it and, on impact, burst into a gigantic ball of flames.

Division Chief David Murphy of the Baltimore County Fire Department noted that the thick wall of smoke from the explosion was so large and high that it was visible for 40 kilometers (25 miles). The crash shut down both the north and south lanes of I-95 immediately. Four vehicles traveling on I-95 were engulfed in the intense fire. Four lives were lost, that of the truck driver and three people in the vehicles caught in the wake of its crash. One man miraculously escaped from his vehicle and ran through the fire to safety.

Ultimately, the incident called on the coordinating abilities of multiple response teams, emergency management systems, and sophisticated intelligent transportation networks. "An event the size of this fuel truck crash can affect transportation and freight on the entire East Coast; therefore, it drew national attention," says Federal Highway Administration (FHWA) Maryland Division Administrator Nelson Castellanos. "With advanced technology, established partnerships, and an incident response plan, [the Maryland State Highway Administration and several other agencies were] able to contain the incident, reroute traffic, and reopen I-95 quickly."

Partnerships Are Key to Success

Working partnerships were an integral component in successfully managing the major traffic incident that occurred on January 13, 2004, on I–895 and I–95 in Maryland. Partnerships that are able to withstand the test of the high-pressure events like the January 13 crash are not made on the spot but are built over time. Some opportunities for collaboration come with local weather emergencies and the multitude of one-time and planned events that take place in the Baltimore-Washington metropolitan area. Perhaps equally significant is the ongoing cooperation among the various groups that meet regularly for the purpose of comparing information, solving common problems, and sharing best practices.

The I–95 Corridor Coalition, for example, is an alliance of transportation agencies, toll authorities, law enforcement departments, and related organizations from Maine to Florida. The coalition provides a forum for key decisionmakers to address transportation management and operations issues of common interest. The mission is to improve transportation services and operations in the corridor through coordinated implementation of advanced technology. Among the coalition's many achievements is an information exchange network that facilitates communication and information sharing during major incidents. (See "Learning from the 2003 Blackout" on page 22.) The coalition maintains a workstation at the Maryland State Highway Administration's statewide operations center to enhance connectivity with the region, and the services that alerted truckers that I–95 was closed are provided through a contract supported by the organization. For more information, visit www.i95coalition.org.

In another example of a key partnership, the Baltimore Regional Operations Committee (B-ROC) comprises more than 20 local jurisdictions and agencies including police, fire, and public works. The committee's goals reflect a dedication to work across jurisdictional boundaries and share resources. In forums convened by regional operations committees, professional relationships are built and an understanding of actions to take during an emergency are shared between the Maryland State Police, county police, State and local transportation managers, and emergency responders. FHWA recently published a primer that encourages and enables regional operations collaboration and coordination for transportation managers and public safety officials from cities, counties, and States within a metropolitan region. B-ROC and CHART are among the examples featured in the guide, *Regional Transportation Operations Collaboration and Coordination*. For more information, visit http://ops.fhwa.dot.gov/RegionalTransOpsCollaboration or contact Wayne Berman at wayne.berman@fhwa.dot.gov.

In addition to these groups, emergency responders meet regularly at training and conferences. In fact, Chief Joseph Herr of the Howard County Department of Fire and Rescue Services and Division Chief David Murphy of the Baltimore County Fire Department were in command and control training together on January 13 when they were advised of the incident on I–95.

Speed and Cooperation

Within minutes of the explosion, the Maryland State Police began receiving calls about the incident from motorists dialing #77 on their cellular phones, and fire and police departments from multiple jurisdictions reported to the scene and its vicinity.

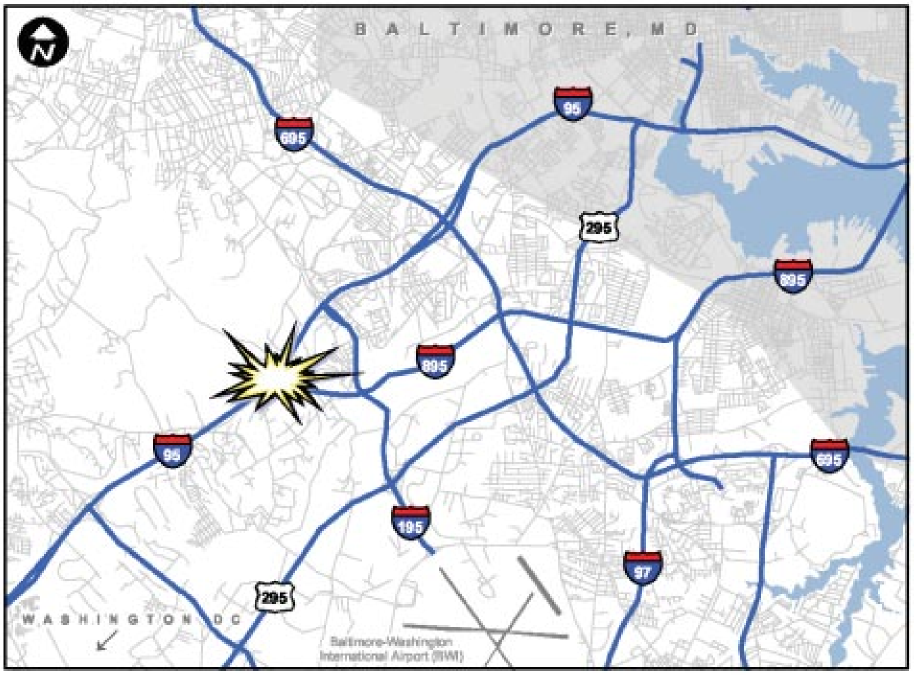
An emergency response technician with the Maryland State Highway Administration (SHA) happened to be driving toward the bridge at the time the truck jumped the overpass. He alerted SHA's Statewide Operations Center and immediately began to shut down the road and redirect traffic. Staff at the SHA operations centers north and south of the incident and at multiple centers in nearby States launched systems to redirect traffic around and away from I-95.

Simultaneously, the Operations Center at the Maryland Transportation Authority (MdTA), which maintains Maryland's seven toll facilities, began to redirect traffic on I-895. Four minutes after the crash, as emergency response vehicles and personnel left their respective stations, Maryland's Coordinated Highways Action Response Team (CHART) changed variable message signs along the I-95 corridor and other feeder interstates in Maryland to inform motorists that I-95 near Baltimore was closed and offer alternate routes.

SHA and local police lost no time setting up the predetermined detours for affected travelers. At 2:57 p.m., staff in the SHA traffic operations centers followed established procedures to alert local police and redirected motorists traveling northbound on I-95 to MD 100, and moved southbound traffic to I-195. The traffic operations centers contacted nearby highway maintenance facilities and mobilized preoutfitted trailers—each loaded with signage, cones, flares, generators, and other specialized equipment needed to reroute traffic at the scene—to the north and south sides of the incident.

Meanwhile, firefighters arrived to find smoke, flames, and heat so intense that it was difficult to know exactly what was inside it all. Emergency responders on both sides of the crash could barely see one another's flashing red lights through the dense smoke.

CHART personnel updated their Web site (www.chart.state.md.us, also accessible through www.marylandroads.com), county police moved to close access ramps onto the interstate north and south of the incident, and staff at the statewide operations center initiated the communications to retime signals on local roadways that would accommodate changed traffic flow on the alternate routes. Other DOTs—in Delaware, New Jersey, North Carolina, Pennsylvania, Virginia, and Washington, DC—activated highway signs to alert motorists about the incident. Up and down the corridor, independent and fleet truckers and couriers received information about the crash through the I-95 Corridor Coalition—a network of transportation agencies, toll authorities, and



This map shows the approximate location of the crash, where I–95 and I–895 meet south of Baltimore, MD.

law enforcement agencies that, among other things, redirects motorists traveling on I–95 in the event of potentially long shutdowns.

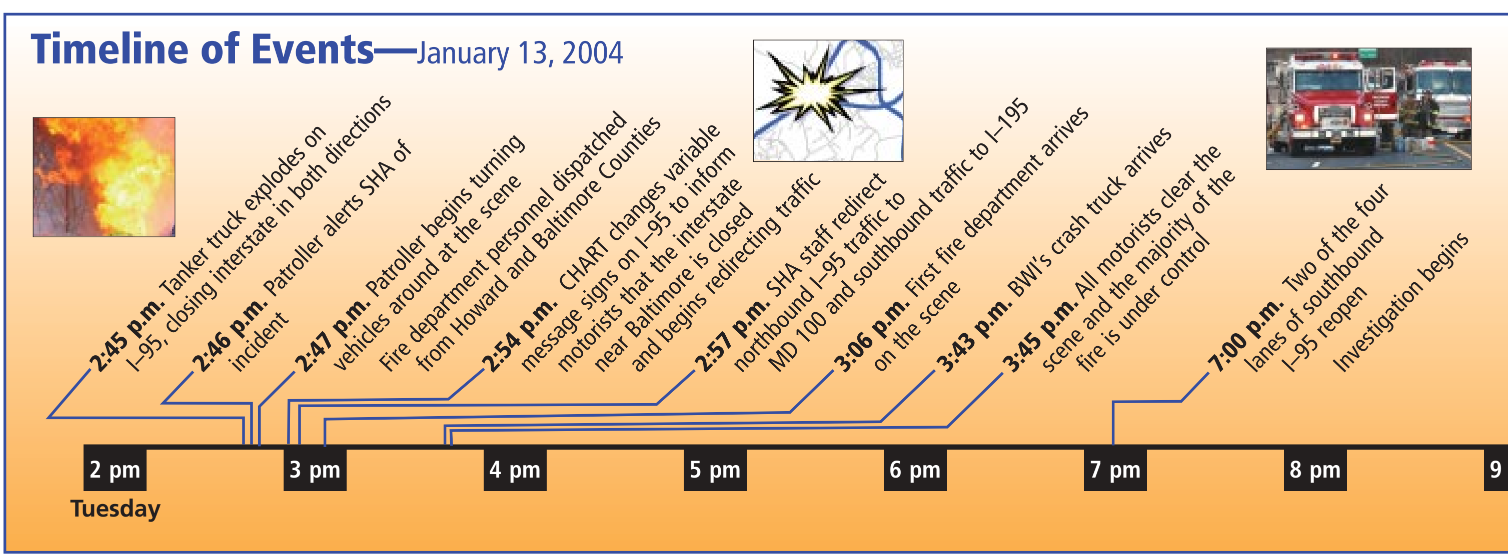
As the evening wore on, more assistance arrived, including investigative teams from the Maryland State Police, the National Transportation Safety Board, and MdTA. Additional SHA highway maintenance crews and specialists from the Maryland Department of the Environment also reported to the scene. Their cooperative efforts facilitated reopening two of the four southbound lanes 4 hours after the incident occurred. By 3:30 a.m. on January 14, just a little over 12 hours from the time of the incident, all northbound and southbound lanes reopened. The backup of diverted traffic never reached more than 4 kilometers (2.5 miles) long, which is common during a normal evening rush hour.

"Governor Robert Ehrlich was in constant contact with us throughout the night, and he made sure that every State resource was available to deal with the aftermath of the incident and safely reopen I–95," says Maryland Transportation Secretary Robert L. Flanagan. "The fact that traffic was flowing on the highway well before the morning rush hour is a tribute to the teamwork and professionalism of the men and women on the scene. They did a fantastic job."

Sergeant Rick Vecera of the Maryland State Police attributes the successful management of the crash to the preparedness and cooperation of those who addressed the emergency and managed the related transportation issues. "Three factors contributed significantly to the operation's success," he says. "The SHA's high-tech operation centers are fully equipped for efficient information management not just locally, but up and down the I–95 corridor. Post-9/11 training has accelerated and enhanced multijurisdictional cooperation and planning. In addition, emergency response staff and transportation managers in the area know one another personally through established professional networks and near-daily interactions during the profusion of planned and unplanned events in Maryland, Virginia, and Washington, DC."

Incident Response

Incident response represents the heart of Maryland's traffic management program. In the early 1980s, SHA implemented its "Reach the Beach" initiative to improve traffic flow during the peak travel season on roadways leading to the beaches on Maryland's Eastern Shore. By the late 1980s, Maryland officials recognized the need for local traffic operations centers to address the ever-growing congestion in the State's metropolitan areas. By 1989, SHA opened its first traffic operations



center to address severe congestion along I–495 near College Park, thus giving rise to what would become the CHART initiative.

Also during the mid-1980s, SHA mapped the Maryland interstate system, interchange by interchange, and identified alternative routes in case vehicles would have to be directed off the interstate. SHA vetted its draft plans with local police, fire, and maintenance crews—the people most familiar with the State's secondary road systems. In 1986, SHA and its partners approved the first Freeway Incident Traffic Management plan and distributed it throughout the State to the appropriate agencies. SHA updates the plan regularly to keep pace with changes in the State's transportation network.

"During a crisis, there is no time to plot detours and assess impacts on intersections," says Sergeant Vecera. "Our tactics are worked out under cool and rational conditions so the plan is ready to be deployed in an emergency. Preparations like the ones in the [Freeway Incident Traffic Management] plan are crucial to traffic management when we experience a shutdown like we had when I–95 was closed by the tanker explosion."

Today CHART no longer focuses on a single need but assists with highway management systems statewide. The response team is now a multiagency organization with a governing board featuring representatives from SHA, the Maryland State Police, MdTA, FHWA, and local governments.

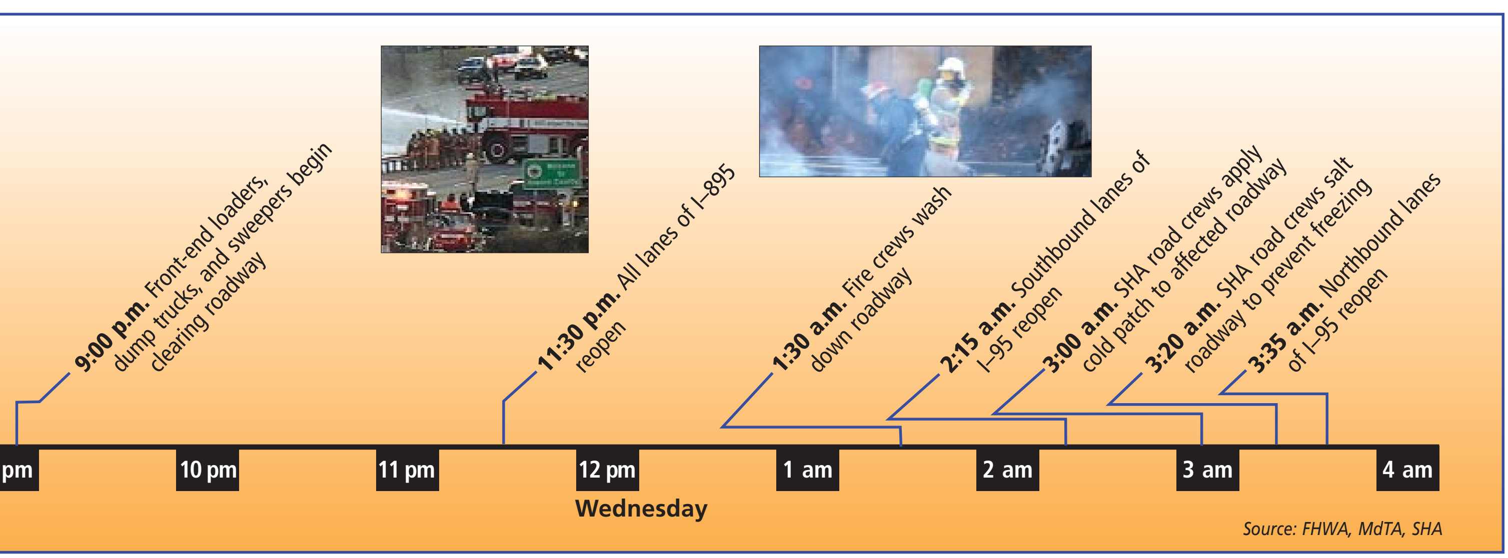
Peter Hammond

Firefighters comb the scene to ensure all the fires are extinguished.

"When the fuel truck exploded on January 13," says State Highway Administrator Neil J. Pedersen, "the systems and teamwork established by CHART were a critical part of the efficient response that helped motorists move to alternative routes and make informed decisions about travel."

SHA also manages its advanced intelligent transportation systems (ITS) through CHART, with the statewide operations center serving as the "hub" for information received from closed-circuit televisions and road sensors—the early indicators of traffic congestion or incidents. A critical component of information sharing is the CHART Web site (www.chart.state.md.us), which typically registers an average of 750,000 to 1 million hits per week. On January 13, the site logged 400,000 hits in a single day.

The #77 cellular call-in system, used extensively by motorists every day—as well as on the day of the incident—is managed by the Maryland State Police and handles approximately 10,000 calls annually. These ITS technologies bolster CHART's information-sharing capacity and give its members the tools to inform motorists and redirect traffic away from the scene of an incident almost instantaneously. CHART also connects directly to other regional systems, so I–95's



Peter Hammond

BWI Airport's crash truck blasts foam on the fire and surrounding area. Local fire units remain ready to assist the BWI firefighters and to manage "hot spots" or small fires that crop up through the foam blanket.

closure was broadcast far beyond the State's borders.

Managing the Fire

Fire companies from Howard and Baltimore Counties dispatched several trucks in response to the 911 calls. Because the event was close to the county line, they did not know who had jurisdictional control until they arrived at the scene. (The Patapsco River forms the border between Baltimore and Howard Counties, with Howard County to the south.) The crash scene was on the south side of the river, putting the fire in Howard County's jurisdiction and the role of incident commander in the hands of Chief Joseph Herr of the Howard County Department of Fire and Rescue Services.

More than 30,283 liters (8,000 gallons) of flammable liquid, tires, and even the asphalt made fighting the fire a monumental challenge. Fortunately, the incident occurred only a few kilometers from the Baltimore/Washington International Airport (BWI). After arriving on the scene and witnessing the intensity of the fire, the county fire units radioed the BWI Fire and Rescue Department to request use of its crash truck, which is equipped with foam.

"The foam acts like a blanket that quickly controls a fire where flammable liquids are present," says Deputy Chief Garry Pace.

BWI's crash truck was on the scene by 3:43 p.m. According to Deputy Chief Pace, the BWI Fire and Rescue Department started pumping more than 2,000 liters (550 gallons) of foam concentrate to rein in the flames.

Local fire units supported the crash truck and crew by shuttling more than 45,000 liters (12,000 gallons) of water from the nearby Patapsco River to mix the foam. The BWI truck had the majority of the fire under control within 1 hour. The fire equipment from the two counties remained to extinguish small fires that continued to burn and to control brush fires on the hillside adjacent to I–95.

Unified Command

Establishing a unified command—taking into account the missions of all responding agencies when making decisions at the scene of an incident—is the job of the incident commander. (See "Coordinating Incident Response," March/April 2004 issue of PUBLIC ROADS.) The incident is partitioned into manageable tasks, and the best qualified response resources are assigned to each need. The organizational structure expands and contracts according to the severity and circumstances of the incident, facilitating a smooth transition of authority during multiagency operations and ensuring that all activity is conducted under a single chain of command. Much like a relay race, once a particular phase is complete, the baton (or authority) passes to the next organization. This approach ensures the safety of responders, crash victims, and motorists, while responders mitigate the impact of the incident on traffic flow and the surrounding community.

Characteristic of the unified command structure, fire and rescue emergency response agencies sometimes are the first on the scene of an incident and normally are the first lead agencies to establish incident command. In the Maryland crash, therefore, the first incident command was established under Chief Herr, who managed the crash within a familiar and practiced organizational structure that is standard for most emergency response situations. Says Major Bill McMahon of the Howard County Police, "There are certain templates put into place to mobilize the command structure, so even though incidents are different, the process transfers from one experience to another."

The command structure helps determine who is in charge of what. For a minor fender-bender involving one blocked lane, the response could be minimal, involving two or three trucks to help control traffic. For more complex incidents, like the I–95 crash where a section of a major highway is shut down, the magnitude of the response will be much greater.

On January 13, with more than 20 agencies at the crash scene and controlling traffic in the surrounding areas, the unified command enabled responders to address the situation quickly and efficiently. Chief Herr's first moves were to meet with leaders from all the attending agencies, establish his command, and assess the situation from the multiple viewpoints represented. Since no rescues were possible, Chief Herr and the other incident commanders established five priorities to ensure continued safe and efficient operations for the duration of the event.

FHWA Supports Traffic Incident Management

FHWA has conducted numerous studies to help State highway agencies and responders assess and improve their skills in managing traffic incidents.

- The *Traffic Incident Management (TIM) Self-Assessment Guide* helps regional program managers gauge the success of their efforts to address traffic incidents and congestion. FHWA also summarized the *National Traffic Incident Management Self Assessment* results for 75 urban areas in the United States. Each area was scored on program and institutional issues, operational concerns, and communications and technology issues.
- The *Traffic Incident Management Handbook* is for both program managers and day-to-day service providers. From design and planning to technology, the manual provides guidance on establishing or improving an incident management program and identifies tools and strategies that can enhance field operations.
- *Incident Management Successful Practices, A Cross-Cutting Study: Improving Mobility and Saving Lives* (FHWA-JPO-99-018) is a 28-page report that shares the experiences of transportation professionals from around the country in deploying ITS technologies to manage traffic incidents. The report covers incident response, site management, interagency coordination, training and leadership, and more.

FHWA also supports research and studies conducted by other transportation organizations:

- The National Fire Service Incident Management System Consortium developed the *Model Procedures Guide for Highway Incidents* to adapt time-tested incident management systems developed by fire services to apply to highway incidents.
- The National Cooperative Highway Research Program's *NCHRP Synthesis 318: Safe and Quick Clearance of Traffic Incidents* surveys policies, procedures, laws, and ordinances from all 50 States regarding the clearance of traffic incidents.
- The I–95 Corridor Coalition's *Quick Clearance and "Move It" Best Practices: Final Report* shares the experiences of transportation agencies and incident responders along the I–95 corridor.

Access these and other documents through FHWA's Office of Operations Web site at www.ops.fhwa.dot.gov/Travel/IncidentMgmt/IncidentMgmt.htm.

- *Protect responders.* The people assisting at the scene needed a safe and protected working environment.
- *Minimize environmental damage.* Acreage along the roadside was burning, and there was concern for fuel contamination in the immediate area.
- *Conduct an investigation and remove victims.* Once the fire was under control, a thorough investigation was needed to understand the cause of the crash and to identify the victims. The investigative work that required road closure was completed during the immediate 12 hours following the incident. Other roadway inspections continued over the next few weeks, requiring I–895 to be closed once for a short period.
- *Maintain traffic rerouting as needed.* Part of protecting responders was to keep the area clear of traffic until it was deemed safe.
- *Complete inspections and repairs to open the highway again.* Reopening the interstate was critical to regional transportation.

(Note that the top priority would have shifted to a rescue mission if there were any survivors.)

The agency leaders met with Chief Herr every 30 minutes and eventually every hour. They set goals to be met before the next meeting and delivered progress reports. "Everyone in the unified command was ready to be a leader or a supporter, depending on the changing roles as the incident needs changed," Chief Herr says. "Throughout the night we saw people step up in anticipation of each other's needs, while others stepped back to allow for a shift in responsibility."

The unified command was needed for the investigative portion of the incident as well. The crash involved two different interstates, I–895 and I–95, under the control of the MdTA Police and Maryland State Police respectively. Representatives from both departments agreed to conduct a joint investigation, with MdTA taking the lead. The joint investigation would help alleviate confusion, avoid duplication of effort between the jurisdictions, and speed up the process.

Peter Hammond

A fleet of firetrucks from the surrounding areas are on the scene.

Peter Hammond

Through the smoke, the burned chassis of the tanker truck and the charred I–895 overpass are visible.

By giving joint press updates, Chief McLhinney, the State Police, and Maryland Transportation Secretary Flanagan were able to keep the message clear and prevent rumors and inaccurate information from being reported to the public. Additionally, Secretary Flanagan briefed reporters on the magnitude of the cleanup and anticipated morning traffic impacts, which helped establish realistic expectations for the public. When road crews opened all lanes of I–95 before the next day's morning rush hour, the team exceeded those expectations. Ultimately, the news coverage on the incident response was positive, and *The Baltimore Sun* published an editorial praising the State and the investment in CHART technology and people.

After the fire was under control and Chief Herr deemed the area safe, the incident command switched to MdTA's Chief Gary McLhinney for purposes of the investigation. Despite the complexity of the crash and its geographic location, the unified command facilitated an organized and effective approach to managing the incident.

Managing the Press

Managing the flow of information *away* from the scene was another challenge. The incident stirred interest from press across the Nation, with about 25 reporters representing radio, television, and print gathered at the scene to collect information. The incident commander turned to public information officers dispatched to the scene to assist with controlling the information released to the public.

Several public information officers were at the crash site—from SHA, the fire and rescue departments, the Maryland State Police, and the MdTA Police to name a few. Major Greg Shipley, spokesman for the Maryland State Police, took the lead and immediately designated a media briefing area. He identified and met with the other information officers, and everyone agreed to cooperate in regular briefings with the media. All participated in the unified command meetings and then met afterward to determine the new information appropriate for public disclosure. The incident commander cleared the messages to the media. Throughout the evening, each public information officer was responsible for disseminating information under the purview of his or her respective organization.

Using Maryland's battery of ITS tools, including variable message signs, highway advisory radio, and the Web, traffic managers and police units launched the quick response that moved travelers away from the incident. Later, after the traffic situation was under control, the story of what caused the crash and speculation on the road closure took on new importance. The media became a valuable ally in sharing current information as people turned to news programs at home or switched to radio programs with regular traffic and news updates. "The public depends on accurate and timely information from news reports," says Major Shipley. "We wanted to be sure to keep reporters in the loop as much as possible while remaining sensitive to the investigative aspects of the situation."

Redirecting Traffic

Within 20 minutes of the incident, SHA personnel and police units implemented traffic detours and disseminated information to motorists about alternate routes. The bulk of the responsibility for detouring motorists fell to SHA, which managed traffic flow away from the interstate. County police assisted by diverting traffic on local roads.

According to Major McMahon, 22 Howard County police officers on the south side of the scene were deployed to 17 traffic posts to move northbound traffic over to the Baltimore-Washington Parkway (MD 295) and U.S. 29. SHA and the Baltimore County Police redirected southbound traffic by diverting motorists from I–95 to I–195 and MD 295. I–895 traffic was detoured to I–695, which is the interstate that encircles Baltimore. The I–695 detour also gave motorists access to the Baltimore-Washington Parkway and I–97 to continue south. Through CHART, SHA staff deployed signal changes that allowed a greater flow of traffic away from the scene on local roads. Cars caught between the detours and

Peter Hammond

A firefighter standing in smoke and foam rakes through debris.

the incident cleared the scene within 1 hour from the time of the crash.

According to Major McMahon, the attacks on September 11, 2001, and local weather events like snowstorms and hurricanes have helped law enforcement and emergency response professionals work together in many cross-jurisdictional situations. "In fact," says McMahon, "Howard County has plans for what we call an 'in-vacuation' that recognizes the traffic effects of what would happen if there was an emergency in Washington, DC, to our immediate south." He attributes part of Howard County's success on January 13 to these preparations for possible terrorist activities.

Once the motorists nearest the scene were evacuated, emergency response and road maintenance equipment were on standby and ready for action as needed. SHA personnel ensured that ambulances, tow trucks, salt and sand equipment, and machinery to repair pavement were staged out of the way but within easy access to the site. At about 7 p.m., the fire units informed the Maryland State Police that two of the four lanes of southbound I–95 could be reopened.

"In Maryland," says Sergeant Vecera, "when an incident involves fire, hazardous materials, or rescue, it is the fire companies who decide when the situation will allow roads to reopen. However, it is seldom a black-and-white decision, so cooperation among all concerned parties at the scene, like we saw on this crash, is what really comes into play."

That cooperation extended to broadcasting the message that two lanes were reopened and mitigating the effects of the inevitable rubbernecking that would take place as motorists passed by the scene. CHART's communications systems updated the information network and variable message signs to inform southbound travelers that lanes were reopened. To minimize rubbernecking, the Maryland State Police requested that SHA move extra dump trucks and variable message signs to the median shoulder between the northbound and southbound lanes to create a wall that blocked the view to passing motorists to help cut down on delays.

Investigation Goes High Tech

Around 7 p.m., Chief Herr declared the scene safe and turned over the role of incident command to Chief McLhinney from MdTA to conduct the investigation. A portion of the work had begun already while the fire was being managed. The Maryland State Police and MdTA Police worked together above I–95 on I–895 to understand why the fuel truck had left the road. Using aerial photos and total stations (mapping equipment) with law enforcement software for investigations, specially trained officers gathered the data needed to conduct a thorough analysis of what had happened.

Today's data-gathering tools enable engineers to create virtual crash scenes for subsequent analyses, rather than keeping the locations closed for on-the-spot evaluations. Having the right technologies and the right people at the right time sped up the investigation. In the past, an investigation of an incident of this magnitude would have required keeping the road closed for considerably longer.

Fifteen weeks after the crash, MdTA released its written report on the incident, and Baltimore's WBAL-TV station aired MdTA's "forensic animation," or reenactment, showing the truck's path as it careened down I–895 and finally over the bridge's concrete barrier. The viewpoint was that of a driver traveling behind the truck. A second animation showed a view from above and how the vehicles on I–95 were caught in the truck's fall.

The National Transportation Safety Board (NTSB) also is conducting an independent investigation of the incident. NTSB's examination will include a review of the operational performance of the truck. According to an NTSB news release on April 16, 2004, the final report is expected in 2005, though safety recommendations can be issued any time during an investigation.

Understanding what happened on I–895 was one portion of the investigation; reconstructing the fire scene on I–95 presented other challenges. The fire units were called in for a new purpose—extricating the bodies from the vehicles involved. "We went into the incident with so many unknowns," says Chief McLhinney. "Were there hazardous materials? How many people were in the vehicles? In fact, until we could really begin to pull things apart, we couldn't be certain how many vehicles had been caught in the fire."

As the investigation progressed, the bodies were removed and taken by the medical examiner for identification. Crash team investigators carefully identified the pieces of debris that belonged to each vehicle. Waiting tow trucks rolled in to remove what was left to a secure location for further examination.

"Being able to remove the debris from the scene serves both an investigation and the need to reopen a highway," says Maryland State Police Crash Team Supervisor Sergeant Krah Plunkert. "Away from the scene, investigators sift through the physical evidence in the debris and collect information that brings the crash dynamics together." He indicated that this enables investigators to take their time and make use of lighting during the day to enhance their investigation.

Cleaning Up and Assessing Damage

Late in the evening, with the rush hour long over, SHA began the final phase of its work on the scene. Equipment and engineers stood by in anticipation of the cleanup. Earlier inspections of the bridge on I–895 permitted reopening the ramp from southbound I–895 to southbound I–95 around 11 p.m.

Front-end loaders, dump trucks, and sweepers went to work for the next several hours on I–95. In the early hours of January 14, firefighters endured below-freezing temperatures as they washed the roadway. Because of BWI Airport's foam truck, little damage had occurred to the I–95 road surface. SHA crews laid thermoplastic tape to increase visibility and applied cold patch to areas in the left lane affected by the crash. Shortly after 3 a.m., road crews salted the washed-down areas to prevent freezing, and, at 3:35 a.m., the northbound lanes of I–95 reopened.

Performance Improvements

According to FHWA Office of Safety Design Director John Baxter, "Traffic incident management embodies FHWA's vital few priorities of safety and congestion mitigation. Our first thought is for the safety of those caught in and near the incident and the safety of the responders at the scene. Our next thought is congestion management and maintenance of the flow of traffic to get people safely to their destinations with minimal delay. Then we think about future opportunities for preventative measures to stop reoccurrence."

The I–95 incident called for assistance from a number of responders, which makes partnerships and team response vital. Since September 11, 2001, transportation personnel, police, firefighters, and their support systems have been alert to the newly realized potential for

large disasters that require multi-agency response.

Communications technology was identified repeatedly as one of the weak points during the event. Cellular communications historically are poor in the area where the incident occurred. Connections were hampered further by the large number of people—motorists, police officers, firefighters, and SHA staff—trying to use their cell phones. Fire and police have an alternative—their 800 megahertz radios—but those airwaves, too, were jammed early in the response, and some of the key leaders did not have radios available immediately. Over time, the responders established small workgroups with each assigned specific radio channels for better connections.

Limitations of current communications technology during a large incident continue to be reviewed. The frequent face-to-face meetings held in the command center helped address the problems and further confirmed the importance of establishing a unified command quickly. Other actions that facilitate success and can be adopted routinely in any large-scale operation include identifying the public information officers and a lead spokesperson to centralize the messages delivered to the press. The regular meetings of unit leaders kept everyone at the scene informed and marginalized information coming from multiple directions.

The primary key to success, however, was not a specific act on the night of the incident. "Our success was marked by the rapport and relationships previously established among the police and fire departments, SHA personnel, medics, and engineers. All the personnel acted in the spirit of collaboration and partnership," says Sergeant Vecera. Professional training, cross-jurisdictional workgroups, and planned events in the area offer traffic management personnel numerous opportunities to work together under less pressing conditions. When strong interpersonal relationships are supported by the appropriate technologies and preestablished response routines, the result is a comprehensive system on ready alert, nearly invisible to citizens but significant in its capabilities.

According to Sergeant Vecera, the next morning's rush hour travelers moved through the area as if the incident had never happened. Technology and partnerships had created an environment for success.

David Buck is the media relations manager with the Maryland SHA, a position he has held for more than 2 years. He was a public information officer for SHA before assuming his current position. His responsibilities include coordination and response to media inquiries related to SHA and the Maryland Department of Transportation. Buck began his career at SHA in 1990 as the first operator at the new traffic operations center in Baltimore. He earned a bachelor's degree at Towson University.

Breck Jeffers is the transportation management engineer in FHWA's Maryland Division. He provides guidance and oversight for federally funded ITS projects and programs in Maryland. Jeffers joined FHWA in 1995 and became an ITS engineer in the FHWA New Jersey Division in 1997. Before joining FHWA he was a traffic engineer with the North Carolina Department of Transportation and an ITS engineer with SHA. He holds a bachelor of science degree in civil engineering and a master's degree in transportation from Morgan State University.

Alvin Marquess is the statewide coordinator for incident management operations for SHA. He began his career with SHA in 1981 as an engineering associate. Marquess also worked in the Accident Studies Division and District 3's Traffic Engineering Office. In 1989 Marquess was one of the initial responders and dispatchers working from Maryland's first traffic operations center to coordinate and manage traffic activities in the Washington, DC, metropolitan area. Marquess serves on committees dedicated to incident management, including the I–95 Corridor Coalition and the Seaboard Incident Management Committee.

The Maryland Transportation Authority Police developed a series of video animations to illustrate how the crash happened from a number of vantage points. This series shows the truck as it travels along I–895 (left), veers toward the right while approaching the overpass (center), and topples trailer-first off the overpass (right). *Source: Maryland Transportation Authority Police.*

by Michael S. Griffith and Barbara Hilger DeLucia

An international scan aimed to find strategies for improving safety data.

Traffic Safety Information Systems

Assessments of State traffic records, promoted by the National Highway Traffic Safety Administration (NHTSA) and the Federal Highway Administration (FHWA), and a recent evaluation of new States for possible inclusion in FHWA's Highway Safety Information System reveal a disturbing trend. The quality of many States' safety databases is eroding, especially in terms of completeness.

With reductions in staff and other resources, a smaller proportion of motor vehicle crashes is reported to State databases than ever before. Also, due to entry backlogs, the information is dated by the time the database is available for use. Although States are increasing their use of geographical information systems (GIS), they are not maintaining adequate records of the roadway characteristics associated with specific locations. Core data elements such as number of lanes, lane widths, shoulder widths, median types, and median widths are missing in many systems, and items such as horizontal curves, vertical grades, intersection features, and interchange features are virtually nonexistent.

"Without accurate crash data for our traffic safety information systems, it is much more difficult to address safety issues," says Susan G. Martinovich, deputy director, Nevada Department of Transportation (DOT). "Our challenge is to find new ideas and ways of doing business and to gather the data we need so we can make better decisions and keep our roads safe."

(Above) This bridge in the harbor of Sydney, Australia, is a signature structure in the heart of New South Wales, one of the sites visited during the October 2003 international scan tour on traffic safety information systems. *Photo: Mike Halladay.*

International Scan Tour

In October 2003, a panel cosponsored by FHWA and the American Association of State Highway and Transportation Officials (AASHTO) conducted an international scanning tour on traffic safety information systems. The objective was to seek innovative ways to build these information systems by learning from countries that have achieved some level of success in designing, developing, and using these systems.

The panel conducted meetings with representatives of government agencies, academia, and private sector organizations in Australia, Germany, and the Netherlands. The discussions focused primarily on:

- General issues of policy, systems, and linkages
- Crash data collection and accessibility of routine and special traffic crash data
- Roadway data collection and the accessibility of data describing roadways, roadside appurtenances, traffic control devices, structures, and traffic volumes
- Other traffic safety issues concerning driver information systems, enforcement, medical data, and adjudication

In addition, the panel held a meeting with the European Commission in Brussels. The commission discussed the European Union's (EU's) efforts to combine minimal data from all of the EU countries into the Community Road Accident Database (CARE) for analysis and reporting of national statistics on injury and fatal crashes.

FHWA and AASHTO selected the scanning team members to represent the diversity of knowledge required to evaluate traffic safety information systems. The 11-member panel represented the American Association of Motor Vehicle Administrators (AAMVA), National Association of County Engineers (NACE), International Association of Chiefs of Police, FHWA, AASHTO, NHTSA, and academia. Technical expertise included engineering, enforcement, driver and motor vehicles, administration and policy, systems and technology, and highway safety research.

Amplifying Questions

The scanning team developed a series of questions to help focus the discussions with the international safety experts and to define the topics and issues of particular interest to the team. The questions referred to general and policy issues as well as detailed issues about crash and roadway data.

The general section included questions related to policy, systems, and data linkages. The crash section contained questions about routine data collection and special crash investigation teams. The roadway section included questions on all types of roadway-related data collection, including inventories, roadside appurtenances, traffic control devices and volumes, and structures.

Due to the time required to cover these critical areas of interest, it was not possible to include questions about many of the other components of a traffic safety information system. During the course of the interviews and presentations, however, the team received supplemental information about driver and vehicle systems that has been included in the final report, *Traffic Safety Information Systems in Europe and Australia* (FHWA-PL-03-020), which is slated to be available by the end of September 2004.

Key Scan Findings

While discussing safety data with representatives of other countries, the scan team did not, for the most part, identify better systems and technologies than those available throughout the United States. The team did, however, discover several themes that drive a strategic approach for the collection, management, and use of safety data in each of the countries.

The themes fell into three areas: strategy, efficiency, and utility. Under strategic issues, the themes included consideration of safety as a core business function of government and the emphasis that the countries place on making resources available for using safety data for decisionmaking. Under efficiency, the focus was on ensuring that the right safety data are collected simply, accurately, and at a reasonable cost. Under utility issues, the themes related to the ability to use the data for research and analysis and the use of analytical tools. The scan team's objectives are to advance these themes in the United States aggressively.

As in the United States, each of the visited countries faces a drop in the documentation of crashes because their police agencies are unable to devote the necessary resources to this task. Each country is looking for new and innovative programs to reduce the fatality rates while working with fewer resources and crash data than ever before.

The most significant similarity among the countries visited and the United States is the fact that fatalities have dropped significantly since 1980. But in more recent years, the numbers have remained essentially constant in the United States and in the visited countries.

The international scan tour visited transportation organizations in Belgium, the Netherlands, and Germany, shown on this map of the European Union (left), and Victoria and New South Wales, shown on this map of Australia (far left).

The scan team included (from left to right): Michael L. Halladay, Office of Safety, FHWA; James W. Ellison, Pierce County Public Works and Utilities and NACE; Herbert Eissman, translator in Germany; Mike Crow, Kansas DOT; Susan Martinovich, Nevada DOT; David L. Harkey, University of North Carolina Highway Safety Research Center; J. Kevin Lacy, North Carolina DOT; Donald J. McNarnara, Region 5, NHTSA; Barbara Hilger DeLucia, Data Nexus, Inc.; Michael S. Griffith, FHWA; Betty L. Serian, Pennsylvania DOT and AAMVA; and Scott MacGregor, California Highway Patrol. Inset photo: Jake Almborg, report facilitator.

Safety As a Core Business Function

Where the similarity ends between the United States and the visited countries is in the emphasis placed on safety as a core business function. The U.S. goal for reducing fatalities is not quite as ambitious as those of the other countries. The European Action Plan that serves as the guiding plan for Germany and the Netherlands, for example, contains the goal of reducing the number of injuries and fatalities by 50 percent from the year 2000 to 2010. The State of New South Wales in Australia has set a goal of about 40 percent by 2010, and the State of Victoria in Australia aims to reduce fatal and serious injury crashes by at least 20 percent by 2007. The U.S. goal for reducing the number of fatal crashes is slightly over 21 percent by 2008.

A strategic safety focus requires top leadership involvement, participation, and monitoring. In each country visited, roadway safety is a core business function and is supported at the highest levels, such as the Minister of Transport. Clear measures to improve roadway safety are set from a national level and communicated consistently—to the States in the case of Australia and the countries in the case of the European Union. Each State or country then develops supporting goals to accomplish the national objectives.

Data Estimates

As in the United States, competing demands have eroded the resources these countries have available to devote to roadway safety. In particular, fewer police-reported crash data are available to identify safety problems and evaluate program successes. Although the visited countries are in the process of developing more advanced data systems, many of their road safety accomplishments have been made without the benefit of robust and linkable data systems. Creative methods for data estimation and linkage strategies are used to limit the amount of information collection required and to help eliminate data inconsistencies.

To obtain sufficient crash data in the Netherlands, for example, estimates are made of the missing and underreported crash data, and safety goals are established based on the estimated data. Numerous methods are used to obtain the estimates. Biannual public surveys are conducted to obtain personal estimates for motor vehicle-, pedestrian-, and bicyclist-involved crashes. These surveys contain numerous questions about safety issues, and a return rate of about 70 percent is achieved through the use of incentives.

Another method is to aggregate insurance data to assist in determining material damage-only crashes and to verify estimates of injury-related or injurious and fatal crashes. Thirdly, hospital data, particularly from emergency room treatments, are factored into the estimates of crashes and injuries.

The Netherlands is seriously considering reducing the number of data elements that are collected by police officers from an already low number of 80 variables to 40 critical data elements. The European Union aggregate database, CARE, requires only 43 data elements. All countries use indepth crash investigation studies to supplement their use of police-reported crash data to study specific safety issues and research.

In addition to using estimates of crash data, the Netherlands instituted an official data-for-data partnership with other agencies to share information. Under a formal agreement between agencies, for example, an entire GIS roadway network file and capabilities for crash data analyses are provided to a local agency in return for that agency's agreement to provide location coding for additions to the existing roadway network in its jurisdiction.

Communication of Safety Programs and Data

Of paramount importance in most of the visited countries is the communication of safety issues, programs, and data to their partners and customers, including the public. Some examples of the strategies used by the agencies include:

- Web-based applications allowing access to statistical crash and roadway data
- Publications, billboards, and other public relations and marketing components to encourage crash prevention and to train motorists to avoid crashes
- A service center staffed to provide a call-in help desk for local jurisdictions and others to obtain statistical crash data and technical assistance
- Marketing efforts to convince drivers to accept personal responsibility for staying safe

All of the visited countries use sanctions on a driver's record as a means of improving motorist behavior and roadway safety. In spite of strong privacy laws in Germany and the Netherlands, information on drivers' histories is shared with law enforcement agencies. In Germany, the overall philosophy is that sanctions lead to rehabilitation, and sanctions are removed from a driver's record at the end of the sanction period. German transportation officials believe that sanctions should not be punitive, but rather that, after a driver makes a mistake, he or she should be able to start again with a clean record. Australia uses a national motorist database so that driver sanctions and history are shared across the States to promote the concept of "one driver, one record, and one license."

The insurance industry serves as a partner in promoting safety in all of the visited countries. In Germany, a consortium of insurance companies supporting highway safety programs provides extensive training for police officers and free software for collecting crash data.

New and Old Technologies

The scan team found numerous examples of the use of new technologies to collect roadway data and the use of existing technologies in new ways. The Australian company ARRB Transport Research's Global Inertial Positioning System Integration Tracking Route Alignment and Crossfall (Gipsi-Trac) is a vehicle-mounted data acquisition system, which uses GPS and sensors to record continuous three-dimensional highway maps and road geometry information. The system can provide latitude, longitude, and height at 10-meter (33-foot) intervals.

In a similar effort, FHWA currently is testing a Digital Highway Measurements vehicle, which has state-of-the-art sensors to capture highway geometrics at levels of accuracy and repeatability not provided by the state of the practice.

An example in Australia of using existing technology in new ways is the use of the digital photographs collected during continuous roadway surveys. The digital photos are available online and are used to support the entry of crash data by helping to identify exact locations and roadway features surrounding a crash.

Another method for obtaining the most benefit from existing technologies is to contract with private firms for the maintenance of equipment such as traffic loops. The contract can require specific levels of service resulting in no payment for times that the equipment is not in operation.

The States visited in Australia provided numerous examples of using technologies to maintain traffic flow and improve the safety of roadway conditions. Uses of technologies included variable speed limit signs during peak congestion periods and adverse weather conditions, traffic loop data to capture tailgating information, cameras for monitoring heavy vehicles, and cameras for ticketing drivers for speeding or running red light signals.

Implementation Strategies

"The true success of an international scanning trip is the ideas brought back to the United States and the implementation of actions to put improved systems and technologies in place," says Michael L. Halladay, director of FHWA's Office of Safety Integration and Delivery. "We have a great set of champions among the team members to define and lead this effort."

AASHTO's Strategic Safety Plan provides a framework for aggressively advancing six major strategic areas: drivers, special users, vehicles, highways, emergency medical services, and management. Under management, the plan includes Goal 21 (improving information and decision support systems) and Goal 22 (creating more effective processes and safety management systems). The scan team believes that these goals are a start for improving traffic safety information systems in the United States.

Also, the team members believe there are seven key themes, which the States may want to consider as they begin the challenging process of improving their information systems. The themes fall under the three areas mentioned earlier (strategy, efficiency, and utility):

Strategy

- Top-level State and national officials need to demonstrate support for safety information systems. A national set of expectations should be created and followed with clear communication to the States. The State leadership, in turn, should work to develop goals and ways to assess the completion of those goals.
- Top-level meetings of stakeholder agencies in the public sector should have a clear focus on safety. Safety should be clearly defined as a core business, and performance measures should be established for assessing safety improvement.

Efficiency

- Data collection should be streamlined and simplified, especially for the officer in the field. This streamlining requires a review of the data requirements with an eye towards quality and collection of only the information needed.
- Current technology can be used more efficiently to simplify data collection and improve overall data quality.
- New technology can be used to collect critical data not already collected, increase efficiency, and improve data quality.

Utility

- Since usage of safety data is a fundamental precursor to improving data quality, marketing traffic safety information is a crucial activity. Through marketing, increased awareness of the issues and the uses of data will in turn support data improvements.
- Analytical tools can help users get the most from the data and support activities such as identifying the optimal locations to make safety improvements, selecting countermeasures to improve locations, and conducting evaluations.

The team will advance these themes in a four-step process through an umbrella strategic project, with the long-range goal of

Mike Halladay

Public surveys are used in the Netherlands to obtain estimates of the number of crashes among bicyclists like these in Amsterdam.

Mike Halladay

In Australia, members of the scan team inspect a vehicle-mounted data acquisition system that uses GPS and sensors to record continuous three-dimensional highway maps and road geometry information.

developing a more comprehensive approach toward working on Goal 21 (improving information and decision support systems). The four steps are: (1) preparing a white paper that states the specific actions and framework that are necessary to achieve more comprehensive safety information systems in the United States; (2) conducting a focus group to validate the white paper, develop additional details as necessary, and start to develop a framework for conducting a national safety data forum with appropriate feedback from various highway safety organizations; (3) conducting a national safety data forum; and (4) preparing final implementation documents. After the forum, the scan team will work with the participants to summarize final recommendations and update Goal 21, and to obtain AASHTO acceptance of the implementation strategies to carry the process to conclusion.

A number of other implementation strategies are being explored in support of the umbrella strategic project. These strategies are:

- Conduct a scan within the United States to determine best practices for collecting, processing, storing, and sharing data.
- Develop a marketing plan for traffic safety information that will increase awareness among the public and political entities of the importance of safety data.
- Enhance and simplify data collection by law enforcement officers by increasing the automation of data, through the use of electronic collection and laptops, and by ensuring that all data collected are necessary and cannot be obtained by any means other than by the officers in the field.
- Expand the use of existing technology to improve and expand databases and support electronic data collection of all types—crash data, roadway features, traffic data, imagery, and driver and medical information. Provide technologies and methodologies to reduce the costs of developing and maintaining systems, and to share costs.
- Develop an implementation approach for the widespread application of safety analysis tools.
- Seek and evaluate new technologies to improve and expand the collection and management of data.
- Conduct a comprehensive review of the need for safety-related data elements, including the benefits and costs of each element collected and stored, and seek methods to remove redundancies and inefficiencies.

These implementation recommendations, along with supplemental recommendations and strategies, are presented in more detail in an internal document, *Scan Technology Implementation Plan.*

Better Data Ahead

FHWA and other organizations are optimistic that improved data lie ahead. Initiatives such as the Model Minimum Uniform Crash Criteria and the "National Model" effort being led by Iowa are moving the highway community in a more safety-focused direction. Data-driven decisionmaking is needed to optimize investments for safety. The Safe, Accountable, Flexible, and Efficient Transportation Equity Act (SAFETEA) proposes an incentive grant program, State Traffic Safety Information System Improvements, to aid States in improving their traffic safety information systems. The program also would encourage States to improve their safety data based upon an assessment of their existing systems and development of a strategic plan for improvements of safety information systems. The potential impact of this program for achieving a future with improved data is considerable.

Michael S. Griffith is the technical director of FHWA's Office of Safety Research and Development. His leadership responsibilities include making sure that the office is conducting research in the most productive areas and is working closely with FHWA's partners and customers. He manages the SafetyAnalyst project and a study evaluating the safety effectiveness of red light running cameras. Griffith is also active in a number of national initiatives such as the Research and Technology National Partnership Initiative and the Highway Safety Manual.

Barbara Hilger DeLucia is president and CEO of Data Nexus, Inc., and has more than 23 years of experience in transportation and highway safety. DeLucia participated in the national effort to revise the NHTSA traffic records advisory. She served on the Transportation Research Board's special task force to define comprehensive computerized safety recordkeeping systems, as vice-chair of the National Research Council Steering Committee for the Study of State Traffic Records Systems, and on the National Safety Council's CADRE task force to define essential data needs for NHTSA and FHWA. She was selected by FHWA and AASHTO to serve as the report facilitator for the International Scan on Safety Databases.

For more information, contact Michael S. Griffith at 202–493–3316 or mike.griffith@fhwa.dot.gov.

Preventing Corrosion in Steel Bridges

by Shuang-Ling Chong

FHWA researchers evaluate the accuracy and reliability of three chloride test kits to determine their performance and accuracy.

Each year the Federal Government and State departments of transportation (DOTs) spend billions of dollars on bridge rehabilitation and maintenance due to corrosion. On bridges, corrosion is most often caused when steel is exposed to atmospheric conditions, such as salt, moisture, and oxygen. To prevent corrosion on bridges, transportation agencies apply a protective coating to the steel.

But according to Dr. Bernard Appleman, a consultant at KTA-Tator, Inc. and former executive director of the Society for Protective Coatings, if the steel has a corrosive agent on it before painting, the protective coating may fail prematurely. "Soluble salts, especially chloride salts that are not removed before painting, are a major source of early and often catastrophic paint failure," says Appleman. If the paint fails prematurely, the resultant corrosion will eventually compromise the structural integrity of the metal. "Ultimately, this paint failure can require extensive bridge maintenance, which is not only costly but also an inconvenience to the driving public," he adds. Therefore, before the bridge painter applies the protective coating to either new steel or a rehabilitated bridge, the surface needs to be evaluated for cleanliness.

Presently, painting specifications almost all rely on visual (or qualitative) measurements to determine readiness for applying protective coatings. However, researchers at the Federal Highway Administration (FHWA) are looking for a more accurate, quantitative measurement that can be used again and again to determine if corrosive elements are on steel prior to applying a coating. One such method may be to test for chloride.

To help bridge coating inspectors better assess the condition of steel prior to painting, FHWA recently evaluated three commercially available chloride test kits that are used to determine the cleanliness of steel surfaces. The objectives were to assess the accuracy and precision of the tests and to identify the factors that influence their performances.

(Above) A painter applies a protective coating to a bridge to protect it from corrosion.

From Visual to Quantitative Assessments

Because contaminants can affect the performance of bridge coatings, inspectors need accurate techniques to assess the cleanliness of the steel surfaces prior to painting. Most methods used today, however, are qualitative or semiqualitative at best.

"All of the cleaning standards today are visual," says Bob Kogler, team leader for bridge design and construction research at FHWA. According to Kogler, assessing steel cleanliness using visual standards can lead to disputes. "An inspector may look at the steel and see indications that it is not clean enough, while the contractor may argue that it is clean enough," he says. "To some degree, even though we have standards, it is almost a matter of opinion because the standards themselves are qualitative."

In 2001, the FHWA Nondestructive Evaluation Validation Center completed a study that evaluated the accuracy of the visual inspection method for determining the condition of bridges. The study showed that inspectors vary considerably in how they complete routine inspections. In particular, they vary in how they assign condition ratings.

"Eventually we need to make our evaluation of steel surface cleanliness a quantitative measure, because it would clear up a big area of disputes on bridge painting jobs," Kogler says. "The measurements [derived from the testing kits] will tell us how chemically clean [the surface] is, not just how clean it looks. And that will give us a much better measure of the potential performance of the paint."

Some applications, such as those in the marine industry, already are moving toward quantitative methods to assess chloride concentrations on steel surfaces.

The Problem with Chloride

Because chloride is the primary surface contaminant and is usually the most corrosive agent to steel, inspectors may be able to test for it before painting steel surfaces. High concentrations of chloride can cause early coating failures, such as rust and delamination, a process in which the coating begins to separate from the steel. Ultimately, the rust and coating

If the steel surface of a bridge is not cleaned adequately before painting, the protective coating can fail prematurely. The steel then will develop corrosion, such as the rust shown on the underside of this bridge. If the bridge is not rehabilitated, the corrosion eventually will compromise its structural integrity.

delamination can destroy the structural integrity of the metal. Chloride is of particular concern for structures that are salted during deicing operations or are located in a marine environment, where the concentration of chloride salts can be high in seawater and spray.

After the steel surface is blasted clean with abrasives or cleaned with high-pressure water, and before a coating is applied, the inspector should assess or test the steel surface for chloride. If the visual inspection or testing indicates high chloride concentrations, the metal must be cleaned again and retested.

Three Chloride Test Kits Evaluated

Currently where specified, coating inspectors use one of three commercial test kits to evaluate chloride levels quantitatively. Generically, the kits are the swab test, the patch test, and the sleeve test.

All three tests use a liquid, either acidic fluid or de-ionized water, to dissolve or extract chlorides on the surface of the steel into a solution. The inspector then tests the solution for chloride concentrations. The swab test relies on wet cotton balls to extract the chloride from the surface of the steel. The patch test uses a syringe containing extraction fluid to draw chloride from the patch test area. And the sleeve test extracts the chloride in a fluid-containing sleeve that is attached to the steel.

According to State DOTs and bridge inspectors, all three tests have shown inconsistent and highly variable results. These inconsistencies may be due to different extraction efficiencies and detection sensitivities in the tests, as well as operator variability.

Therefore, FHWA researchers investigated the variability and limitations of the test methods to establish techniques that may be used to obtain reliable and accurate chloride concentration test results.

Experimental Procedures

The researchers analyzed steel panels in a vertical position. Four different levels of chloride concentration, ranging from 3 to 30 micrograms per centimeter squared ($\mu g/cm^2$), were applied to the panels to determine if the chloride concentration affected the validity of the results.

An industry rule of thumb is that after blasting, a bridge should be painted within 4 hours. Therefore, the researchers performed tests under three conditions that fell within this timeframe: within 1 minute after panels were doped (that is, artificially contaminated with chloride), after aging doped panels at high heat and moderate

Three Chloride Test Methods

Following are detailed descriptions of how the researchers conducted tests using the three kits.

Swab Test

The researcher extracted chloride from a surface area of 150 cm^2 (23.25 in^2)—a 15-cm-long by 10-cm-wide steel panel—using 15 milliliters, ml (0.51 fluid ounce, fl oz) of de-ionized water for cotton swabbing. To reduce dripping, only one-third of each of the four cotton balls used for swabbing was soaked with de-ionized water. The researcher then absorbed the remaining liquid with an additional cotton ball and used an ion detection strip to measure the concentration of chloride in the extracted solution.

Patch Test

The researcher glued a patch securely onto the steel surface, covering an area of 12.25 cm^2 (1.89 in^2). The researcher then injected 1.5 ml (0.05 fl oz) of extraction fluid into the patch, then extracted two-thirds of the fluid from the patch and reinjected it to mix the fluid more thoroughly. The researcher then rubbed the patch with a finger for 1 minute to promote chloride solubility. Next the patch was rinsed with an additional 1.5 ml (0.05 fl oz) of extraction fluid. Finally, the researcher combined the two extractions and titrated the resulting 3 ml (0.1 fl oz) of extract with reagents included in the kit.

Sleeve Test

The researcher poured 10 ml (0.34 fl oz) of extraction fluid into a sleeve and then attached the sleeve firmly to the steel panel. The researcher then lifted the free end of the test sleeve and held it upright with one hand to allow the extraction fluid to make contact with the test surface. With the other hand, the researcher massaged the solution through the test sleeve against the steel surface for 2 minutes. The researcher then removed the test sleeve and used an ion detection tube to test the solution for chloride concentration.

A technician uses high-pressure water to clean a section of steel.

humidity for 4 hours, and after aging doped panels at high heat and high humidity for 4 hours.

The detectors for the swab, patch, and sleeve tests are an ion detection strip, four bottles of titration liquids, and an ion detection tube, respectively. Because the patch test can use two different fluids, acidic fluid or de-ionized water, the researchers conducted additional tests to determine which fluid recovered the most chloride. Since the researchers found that acidic fluid extracted more chloride than de-ionized water, acidic fluid was used in the patch test.

In all, the researchers evaluated each kit under 12 different conditions (4 chloride concentrations and 3 aging conditions) to determine how chloride concentrations and aging affect the accuracy of the test. Each test was performed three times by three different operators at the Paint and Corrosion Laboratory at FHWA's Turner-Fairbank Highway Research Center (TFHRC) in McLean, VA.

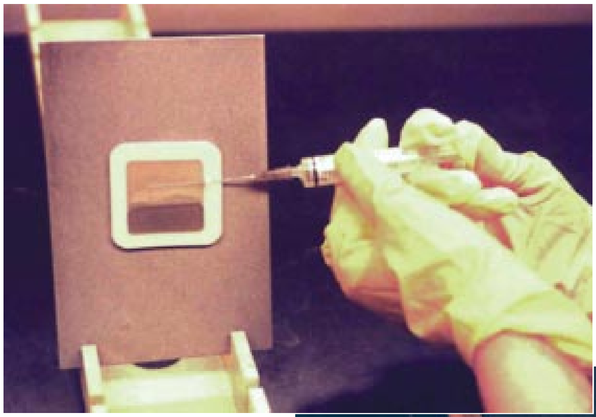
Comparing the Results

The researchers identified strengths and shortcomings for each test. The research team acknowledges that since these tests were conducted in a laboratory, where procedures were carefully controlled, the experimental results may be better than would be expected in the field.

Of the three tests, the swab test recovered the highest amount of chloride and also offered the most reproducible data. For freshly doped steel (that is, a specific amount of chloride applied to the steel for testing), the swab test recovered approximately 70 to 100 percent of the chloride. This test also had the least variability.

The swab test uses an ion detection strip, which can detect chloride concentration only above 30 parts per million (ppm). The large extraction area, however, compensates for the detection limit. The researchers found that the lowest level of chloride detection possible under the laboratory conditions employed was 3 µg/cm^2.

One shortcoming of the swab test is that it must be conducted very carefully, which may be challenging in the field where a test operator or inspector may be high on a ladder testing steel overhead. Because it is conducted in an open environment, water can drip and evaporate easily, which will result in reduced chloride recovery and therefore imprecise results.



(Left) For the patch test, a researcher injects chloride extraction fluid into a patch on a vertical steel plate.

(Below) For the swab test, a researcher uses a cotton ball and de-ionized water to detect and extract chloride from the steel plate.

Unlike the swab test, the patch test is a closed extraction system, which prevents fluid evaporation and loss. However, the operator may still lose fluid if either the patch is not adhered to the steel surface firmly, or if the syringe, which is used to extract fluid, is improperly inserted into the patch. In either case, the loss of even a small amount of extraction fluid will result in inaccurate chloride measurements.

The patch test, with titration liquids used as a detector, also provides high chloride recovery. But the results were found to be the most unreliable of the three tests, as indicated by a higher margin of error. One potential cause for the error is the variability in drops needed to reach the titration end point (that is, color change). If the color change falls between two drops, some operators will use an extra drop while others will use one drop less. The number of drops used may vary by operator, or the same operator may use a different number of drops for each test conducted. This variation in the number of drops will affect chloride concentrations.

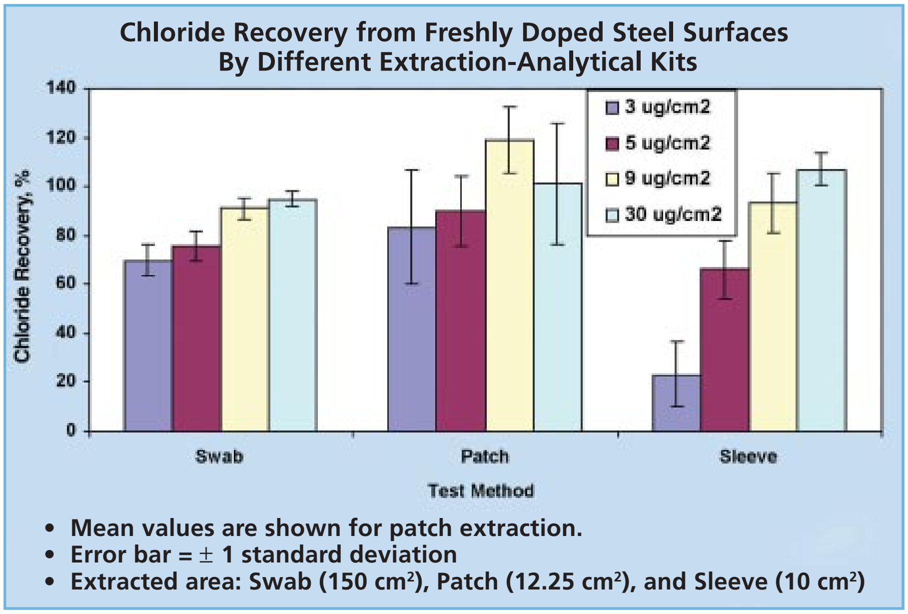
An additional shortcoming of the patch test is that it only indicates minimum and maximum values rather than actual values. However, a coating inspector could be conservative and use the maximum value to determine whether to proceed with a painting job.

A final shortcoming of the patch test is that the acidic fluid requires

Parameters of the Three Chloride Extraction Test Methods

	Swab Test	Patch Test	Sleeve Test
System type	Open	Closed	Closed
Detection method	Ion detection strip	Titration	Ion detection tube
Area, cm^2	150	12.25	10
Extraction fluid, ml	15	3	10
Area (cm^2)/volume (ml)	10	4.1	1
pH value of extraction fluid	De-ionized water, pH = 6.7	Acidic, pH = 3.9	Acidic, pH = 4.2

The table shows the system type, detection method, area of extraction, extraction fluid volume, ratio of area to fluid volume, and pH value of the extraction fluid for each of the three test kits. *Source: FHWA.*



The bar graph compares the chloride recovery by the swab, patch, and sleeve tests at four different chloride levels: 3, 5, 9 and 30 micrograms per centimeter squared (µg/cm^2). For all tests, the chloride recovery decreased with decreasing chloride concentrations; it decreased from 100 to 70 percent, 120 to 85 percent, and 100 to 25 percent for the swab test, patch test, and sleeve test, respectively. The graph also shows the error bar for each of the tests, indicating how reproducible the results are. A low standard error indicates high reproducible results, while a high standard error indicates low reproducible results. All three tests showed some standard error in the tests. The standard error was lowest for the swab test and highest for the patch test. *Source: FHWA.*

mercury nitrate as one of the titrants. Because mercury is a hazardous waste, the operators or inspectors must follow strict guidelines when disposing of the fluid.

The sleeve test, like the patch test, is a closed system with little risk of fluid loss, but extraction fluid can be lost if the sleeve is not adhered to the steel surface firmly. If fluid is lost, the test will generate unreliable chloride measurements.

The sleeve test was more effective at recovering chloride at higher concentrations than at lower concentrations. The low rate of chloride recovery at lower concentrations may be due to the low sensitivity and unclear color separation at the low reading end of the ion detection tube. The sensitivity can be increased if the extraction volume is reduced or extracted area is increased. The sleeve test had a margin of error that fell between that of the swab and patch tests.

Humidity Affects Test Results

An important finding of the research is that heat and humidity will affect test results. When the doped panels were aged at a high temperature—37 degrees Celsius (98.6 degrees Fahrenheit)—for 4 hours under two different humidity conditions, the chloride recovery was less than that of freshly doped panels. However, the researchers noted a considerable difference between moderate and high humidity. At 57 percent relative humidity, the chloride recovery was reduced only slightly. But for all three tests, chloride recovery decreased considerably at 78 percent relative humidity.

The researchers speculate that low levels of rust formed after the steel was exposed to high levels of heat and humidity for 4 hours. The invisible rust entrapped the chloride, making it more difficult to extract.

These results suggest that inspectors should determine the surface chloride concentration as soon as possible after blasting. Any delay, especially in hot and humid environments, may result in erroneously low chloride values. If these low chloride values fall within the acceptable limits for the protective coating, an inspector may decide to apply the coating to a steel surface that in reality has unacceptable levels of chloride trapped under invisible rust.

Using the Research Findings

Although additional research is warranted, the findings from the FHWA study may provide valuable information that coating inspectors can apply in the field today.

"A coating inspector could utilize the results of [the] research by selecting a technique based on the levels of chloride expected and the environmental conditions encountered," Appleman says. "For example, if the surface was exposed to the sun on a hot day, the coating inspector might choose to use a method other

Summary of Test Results

	Swab Test	Patch Test	Sleeve Test
Chloride concentration	High (10)[a]	Medium (4.1)	Low (1)
Loss of extraction fluid	Yes	No, if patch adhered to steel firmly	No, if patch adhered to steel firmly
Minimum threshold	3 µg/cm^2	~ 1 µg/cm^2	~ 5 µg/cm^2
Reproducibility of results	High (for tests above 30 ppm)	Low (only minimum and maximum values given)	High (for tests above 9 ppm)
Detection sensitivity	> 30 ppm	>1 µg/cm^2 (4 ppm)	> 5 ppm
Detection range	30 – 600 ppm	1 – 50 µg/cm^2	1 – 50 ppm (= 1 – 50 µg/cm^2)

a: Ratio of extracted area to extraction fluid volume.

The table summarizes the results for the three tests evaluated, noting the chloride concentration of the extracted fluid, the degree to which extraction fluid is lost, the minimum test threshold, reproducibility of detection method, detection sensitivity, and detection range. *Source: FHWA.*

Tips to Improve the Accuracy Of Chloride Tests

Because all chloride detection tests are highly sensitive to the testing procedure, the research team developed the following suggestions to help improve the accuracy of the tests.

- Conduct extractions as soon as possible after the steel is blasted because exposure of clean steel to high heat and humidity can reduce the amount of chloride extracted.
- Obtain complete training in the extraction method being used.
- Verify the accuracy for each batch of detector using known chloride standards before performing field tests. Furthermore, extract steel panels that are freshly doped with a solution of known chloride concentration to test the operator's technique.
- Use extreme caution to avoid losing fluid during the extraction.
- Extract large areas using smaller amounts of extraction fluid to increase the sensitivity of the test.

than swabbing, since that method would result in inaccurate chloride recovery due to water evaporation during extraction in open air. As another example, if the acceptance criterion was low—such as 3 micrograms per square centimeter—a coating inspector would avoid using a method with low sensitivity."

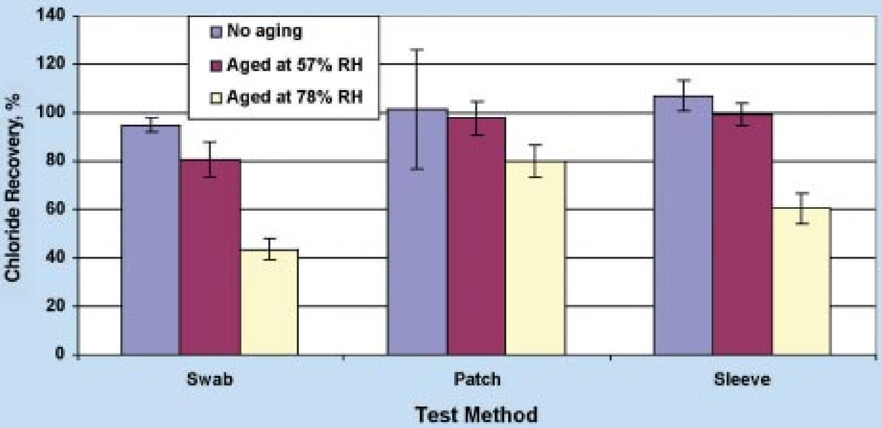
From the Lab to the Field

The next step would be to evaluate the performance of the chloride recovery test kits in the field to determine whether quantitative tests should be incorporated into specifications for bridge painting. "This research [was conducted] in a laboratory under controlled conditions, which is appropriate for basic research," Kogler says. "[But] we need to evaluate these methods under field conditions, in cooperation with State bridge owners, to see what kind of improvements we need to make to these tests or procedures before we put [them] in our specifications."

Future research will not only evaluate the accuracy and reliability of the tests but also the usability. "Imagine climbing up on a ladder to a bridge abutment, with traffic overhead on the bridge," Kogler says. "You have a syringe of water, and you need to glue this sticky thing on the bridge, and use a dropper. It takes a while to run the test. Even though [the tests] were designed to be used in the field, we need to find out how usable they really are."

The big question is whether bridge inspectors should be required to test for chlorides for all bridge painting jobs right now, and whether the tests are accurate and user-friendly enough. In laboratory tests, the researchers found that the testing must be conducted very carefully to ensure consistency of results. "This research provides some of the first real unbiased data on these test kits," Kogler says. "The analysis gives us a snapshot of where the technology is now and where we need to go to improve it."

Chloride Recovery from Steel Surface Doped With 30 μg/cm² After Different Aging Conditions



- Swab extraction solution: pH = 6.7
- Patch extraction solution: pH = 3.9
- Sleeve extraction solution: pH = 4.2
- Mean values are shown for patch extraction.
- Error bar = ± 1 standard deviation

The bar graph shows the effect of aging on the chloride recovery for the swab, patch, and sleeve tests. For the test panel that aged at 37 degrees Celsius (98.6 degrees Fahrenheit) and 57 percent relative humidity (RH) for 4 hours, the chloride recovery is almost 100 percent, similar to that from the freshly doped panels. However, after the test panels were aged at 37 degrees Celsius and 78 percent relative humidity for 4 hours, the chloride recovery decreased significantly for all the tests. The recovery decreased from 100 to 40 percent, 100 to 80 percent, and 100 to 60 percent for the swab, patch, and sleeve tests, respectively. The graph also shows the error bar for each of the tests. All three tests showed a similar, moderate standard error for the aged tests. *Source: FHWA.*

Shuang-Ling Chong, Ph.D., has been a senior research chemist at FHWA since 1989. Chong's responsibilities have included managing the Paint and Corrosion Laboratory, studying accelerated testing of bridge coatings, and developing methods for characterizing coating materials and failures. Chong earned her Ph.D. in physical chemistry in 1969 from Rutgers, The State University of New Jersey.

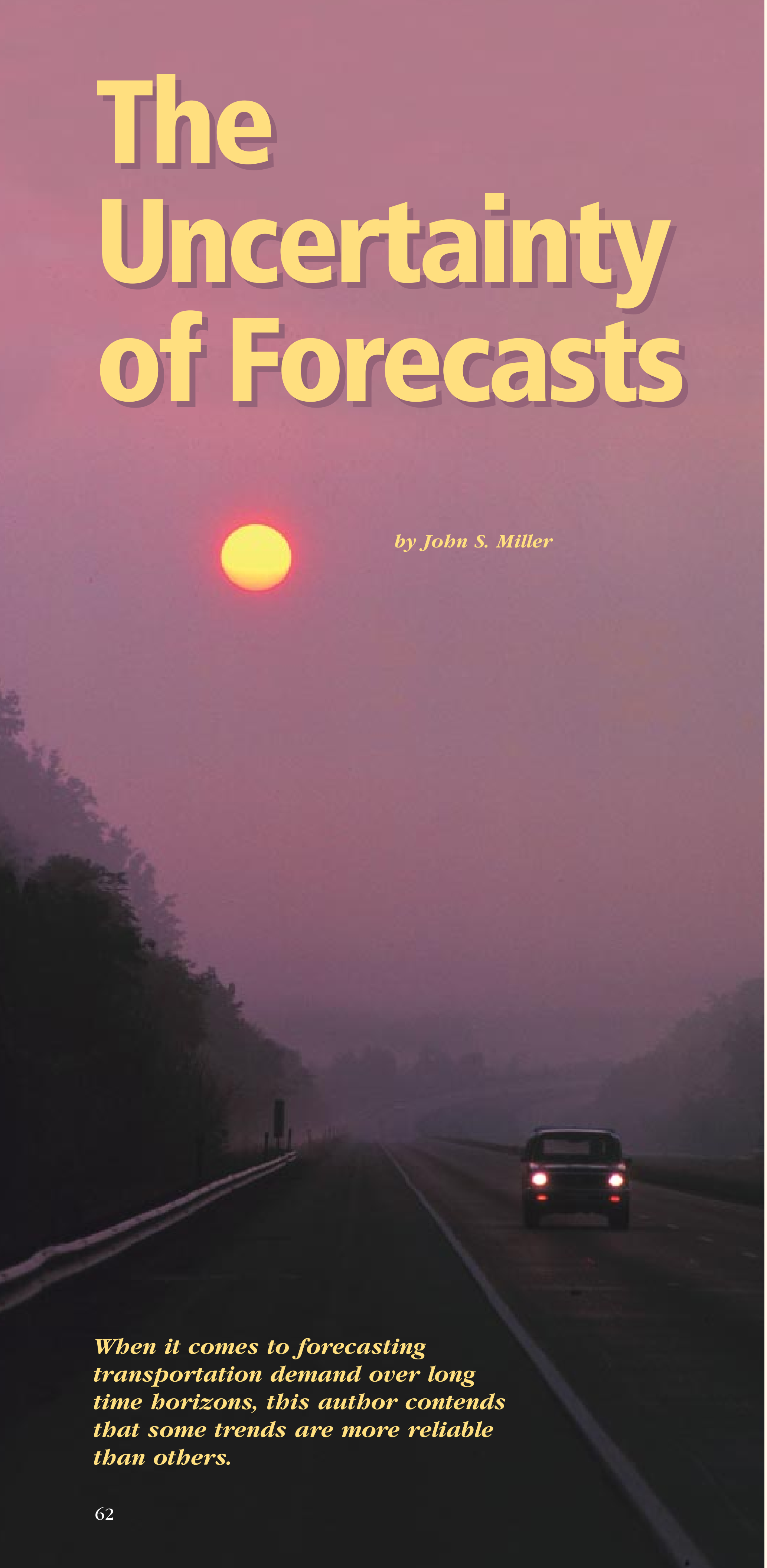
Additional details regarding the experimental methods used in the study are available in Dr. Chong's article, "Intra-Laboratory Assessment of Commercial Test Kits for Quantifying Chloride on Steel Surfaces," published in the Journal of Protective Coatings and Linings, *p. 42, August 2003. For more information, contact Shuang-Ling Chong at 202-493-3081.*

The author would like to thank Yuan Yao and Muriel Rozario of Soil and Land Use Technology (SaLUT), Inc. for their input in preparing this article. The author also would like to acknowledge the vendors of the three test kits evaluated, who were very cooperative in this study.

The Uncertainty of Forecasts

by John S. Miller

When it comes to forecasting transportation demand over long time horizons, this author contends that some trends are more reliable than others.



Transportation planners often are asked to predict socioeconomic, demographic, and land use trends that will affect future demand for transportation services. But legitimate questions immediately arise: How well can such trends be envisioned, in what areas are forecasts likely to be imperfect, and how can such uncertainties be imparted to decisionmakers? The impetus for investigating the accuracy of predictions stemmed from background work conducted to support the development of *VTrans2025*, Virginia's statewide, multimodal long-range transportation plan, begun in 2000 and scheduled for completion in 2005.

A century of national transportation data suggests that predictions over a long time horizon are not equally accurate for all types of information. A forecaster looking 25 years ahead at any point between 1900 and 1975 probably could have predicted about half of the transportation-related trends accurately at the national scale. Predictions for *socioeconomic* factors, such as population, ethnicity, employment, income, and household sizes, are generally feasible, albeit imperfect, provided the geographical area is adequately large. Predictions for trends based on *technological innovation*, *social change*, or *legislative* factors, however, are much more difficult.

Many themes in transportation planning, such as modal split for passenger and freight travel, land use legislation, potential improvements in technologies that would help transportation operations, and public willingness to support additional transportation infrastructure, fall into the latter category. Within long-range transportation plans, one should clearly indicate those factors that are likely to be predicted accurately. There might be other predictions that are more difficult to get right.

(Left) A lone vehicle travels down a Virginia highway at dusk. Accurately predicting future demand for transportation infrastructure like this highway can be challenging, as technological innovations and social or political developments can cause unforeseen shifts in trends. *Photo: Ed Deasy, Virginia Transportation Research Council.*

Forecasting Trends Over a Long Horizon

Long-range transportation plans, with horizons of 10 years or greater, often are viewed as a process for enabling decisionmakers to evaluate the strengths and weaknesses of various transportation alternatives. These plans necessarily rely on a variety of projections regarding the future: How many people will live in a region; how much will they earn; what kinds of jobs will they have; and where, when, and by what mode will they travel?

To support the creation of *VTrans2025*, staff from the various modal agencies in Virginia—the Virginia Department of Aviation, Virginia Department of Rail and Public Transportation, Virginia Department of Transportation (VDOT), and the Virginia Port Authority—asked the Virginia Transportation Research Council (a joint venture between VDOT and the University of Virginia) to identify key socioeconomic trends likely to affect transportation demand in 2025. The trends report, *Expected Changes in Transportation Demand in Virginia by 2025* (available at http://virginiadot.org/vtrc/main/online_reports/pdf/03-tar5.pdf), is *not* the *VTrans2025* statewide multimodal plan; rather, the trends report was designed simply to produce supporting information for developing the plan. This supporting information was expected to identify trends in four areas:

1. *Historical and projected socioeconomic trends,* such as population, employment, and personal income. For example, how will the age of Virginia's population change by 2025?
2. *Relevant changes in public policy, legislation, and technology*. Specific topics include local legislation on growth management, improvements in traffic operations, and Federal funding.
3. *Freight projections and changes in market share* for the various modal freight movements. For example, what will be the value of freight shipped by the various modes of air, rail, and truck by 2025?
4. *Passenger travel trends,* including mode choice, automobile ownership, and changes in vehicle miles traveled (VMT).

One key question that arose during preparation of the forecasts is, *Why is it not possible to forecast all trends for all Virginia jurisdictions, down to the county and city levels, equally well to year 2025?* The State desired a high level of detail for consistency among the different agencies, so that all trends would be forecasted to the same level of geographic detail and for the same horizon year. Another reason for the high level of detail was more fundamental: the *VTrans2025* Technical Committee wanted to map transportation services to expected transportation demand. A legitimate question was raised: If one can predict a statewide population for the year 2025, is it also possible to predict other trends, such as the modal splits for passenger miles traveled or tons of freight shipped? Further, why not forecast those trends not just at a statewide level of detail but also at the city or county level? To answer these questions, researchers at the Virginia Transportation Research Council (VTRC) examined national-level data to determine how well forecasting attempts in the past would have predicted current conditions.

A related question is the importance of the horizon year 2025, established by decisionmakers as the target year. Even if predictions are feasible, is it desirable to make projections to the year 2025? One view is that because transportation represents such a broad set of phenomena, different elements will have different planning cycles.

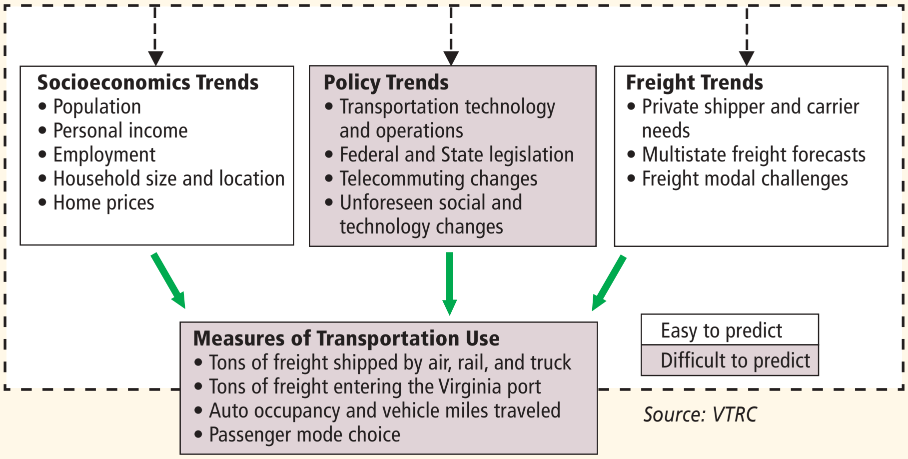
A second view is that it is more important for planning horizons to be consistent. For example, during a hearing on transportation and air quality before the U.S. Senate's Committee on Environment and Public Works in July 2002, Federal Highway Administrator Mary E. Peters noted that air quality plans often cover 5 to 10 years, compared with the 20-year horizon for transportation plans. She also noted that some stakeholders have suggested bringing the planning horizons and frequency of updates closer together, either by lengthening the former or shortening the latter.

A third response is that even longer horizons are necessary, because 20 to 30 years is a relatively short time frame for the infrastructure impacts of transportation on land use to take effect. Given these three responses, a longer forecast horizon may facilitate more complete analysis of transportation and land use, provided that consistency among various types of plans can be achieved.

Types of Data Forecast to 2025

To support *VTrans2025,* trends and forecasts were developed across four main areas: socioeconomic trends, public policy changes, multistate freight requirements, and measures of transportation use. Socioeconomic trends—population growth, income and employment changes, and household size and location—are a reasonable starting point for any long-term plan since these factors affect how the State will evolve and are somewhat stable over time at the statewide level.

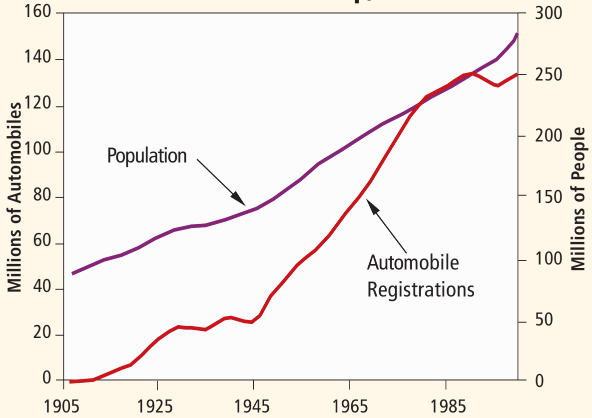
Sources of Demand Affect Measures of Transportation Use



Source: VTRC

The figure shows how various trends—socioeconomic, policy, and freight—feed into predictions about transportation use. The dashed arrows signify potential feedback between measures of transportation use, such as VMT, and trends such as home prices.

National Changes in Population and Automobile Ownership, 1907–2000



The graph shows national trends in population and automobile registrations in the United States from 1907 through 2000. Both have risen since 1907 but at different rates. Since approximately 1945, automobile registrations have outpaced population growth. Researchers could predict this steady increase fairly easily.

Public policy changes in the areas of national legislation, consumer needs, and transportation technology may significantly alter how transportation services are delivered. Multistate freight requirements also influence transportation demand because freight movements can use Virginia's transportation network or may bypass the State altogether. These three categories—socioeconomic changes, policy changes, and freight changes—affect sources of transportation demand. And the way the transportation system responds to these sources of demand may be expressed as the fourth category—measures of transportation use—reflected by passenger VMT, mode choice for passengers and freight, tons of freight shipped, and travel time.

Although these four areas are presented as discrete sections for ease of illustration, they are related. Rising incomes, for example, generally are associated with increased travel. Rising home prices in a close-in suburban county may cause some residents to locate farther away from their jobs, thereby increasing passenger VMT. The resultant traffic congestion may in turn cause prospective home buyers to place a premium on close-in suburban homes.

Rules of Thumb for Forecasting

Generally, more faith may be held in trends that are less susceptible to sudden change, relatively large in geographical scope or based on a relatively large data set, and projected over a shorter rather than a longer horizon. For example, 2010 population forecasts for the State of Virginia are more reliable than 2025 home price forecasts for Charlottesville (a small- to mid-sized city southwest of Washington, DC) for three reasons:

1. Historically, population trends have grown at a relatively steady rate without sudden increases or decreases, whereas home prices can drop suddenly because of market conditions, changes in school quality, or changes in an area's employment outlook.
2. Virginia is much larger than Charlottesville; the likelihood of a spurious trend emerging is much greater for a small city than it is for an entire State.
3. The likelihood of an unforeseen change occurring is greater over the next 25 years than over the next 10 years.

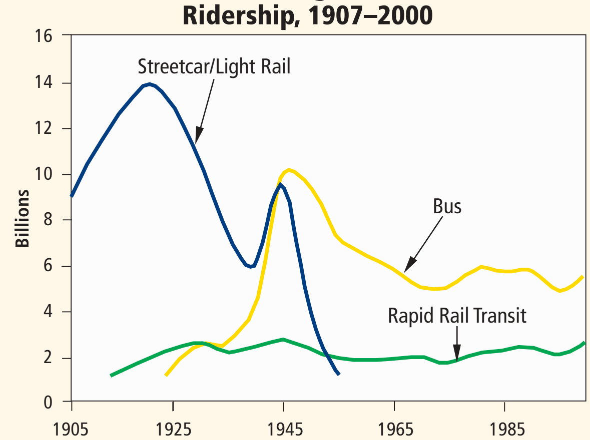
A fourth factor that influences the ability to make predictions is that trends driven by market or socioeconomic mechanisms appear to be easier to predict than those driven by legislative fiat. The continued decline in agriculture-related employment, for example, can be forecast relatively easily, since the increased efficiency of farming techniques and the higher economic benefits of land used for purposes other than agriculture are trends that are expected to continue based on market principles. In contrast, projections of land use trends based on local zoning ordinances or local plans are less reliable, since they are subject to change and receive pressure from market forces, popular will, or political interests.

A fifth factor is the quality of data and the availability of multiple data sources. Population data for the State of Virginia, including forecasts, are available from the U.S. Census Bureau as well as private data sources. Other types of data, however, are limited, making forecasts more difficult. Freight transport data, for example, historically have been difficult to acquire owing to the proprietary nature of commodity flows and shipper characteristics.

Case Study in Mode Choice

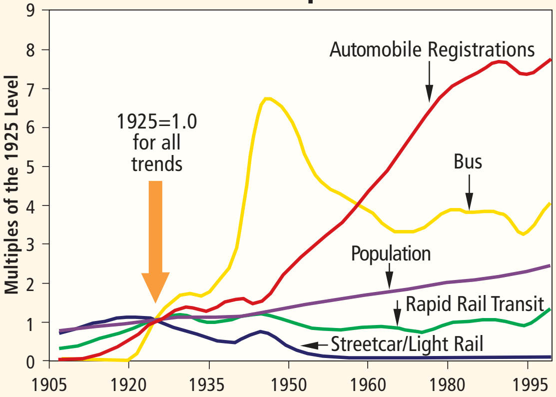
Forecasts for socioeconomic measures such as population, income, and employment in 2025 are readily available at the metropolitan, State, and national levels. Within the realm of policy, however, forecasting precise legislative, technological, and social trends a quarter century into the future generally is not possible. A practical reason is that over a 25-year horizon, identifying key social responses that may result from technological or organizational innovations, economic changes, or political events is impossible. Anecdotal examples of unforeseen disruptions include the increase in business

National Changes in Transit Ridership, 1907–2000



This graph shows national trends in light rail, rapid rail, and bus ridership in the United States from 1907 through 2000. Unlike the steady increase in automobile registrations, the trends for streetcar/light rail, rapid rail transit, and bus ridership have experienced periods of growth and decline. Consequently, predicting trends for these modes of transportation is more difficult. A trend line forecast made in the early 1900s for the use of these technologies over this multidecade horizon would have had limited value. *Source for both graphs: VTRC, using raw data from Bureau of Transportation Statistics, U.S. Census Bureau, American Public Transportation Association, and Saltzman, A. "Public Transportation in the 20th Century."*

Change in Transit Ridership, Population, and Automobile Ownership Relative to 1925



This figure shows the change in transit ridership, population, and automobile ownership relative to 1925. The five trends (population, automobile registrations, streetcar/light rail, rapid rail transit, and bus ridership) now are presented as ratios to their 1925 levels. For example, in 1950, bus ridership was about six times its level in 1925. On the other hand, by 1950, streetcar ridership had dropped to a fraction of its 1925 level. *Source for both graphs: VTRC, using raw data from Bureau of Transportation Statistics, U.S. Census Bureau, American Public Transportation Association, and Saltzman, A. "Public Transportation in the 20th Century."*

applications of the Internet in the 1990s, the personal computer revolution in the 1980s, the rapid rise in purchases of television sets between 1947 and 1952, and the number of persons educated under the G.I. Bill following World War II.

The following case study in predicting the modal split for passenger travel suggests the difficulty of foreseeing fundamental policy shifts. The example suggests that envisioning technological and social change is a much more difficult task than extending population or employment trend lines.

A century of data provides some perspective on forecasting social and technological developments related to transportation. Looking backward with the perspective of hindsight, A. Saltzman writes in an article, "Public Transportation in the 20th Century," in *Public Transportation* that the trends that occurred are not surprising. At the turn of the century and peaking around 1920, for example, streetcar ridership was strong, owing to technological change (electrifying horse railways) and land use change (dispersion of cities).

The fact that public transportation ridership, including street cars, light rail, rapid rail transit, and bus, was lower in 1935 than in 1930, especially in light of increasing population (and no corresponding increase in automobile registrations), can be explained by an economic change (the Great Depression). Social change (World War II) explains the increase in all public transportation modes in the early 1940s, whereas economic and land use changes (increasing incomes and greater dispersion of cities) may be reasons for the automobile's subsequent dominance.

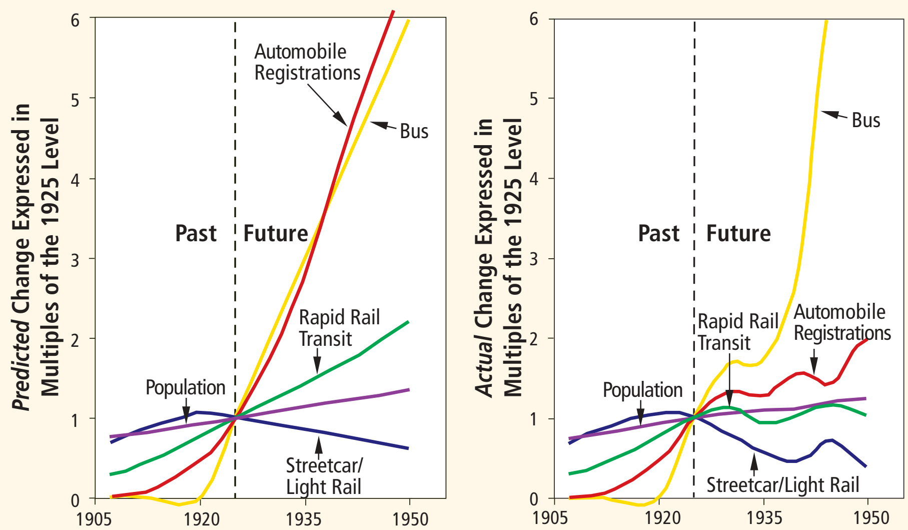
In addition, Saltzman notes that the shift from a 6-day to a 5-day workweek may have contributed to the near-demise of rapid rail transit, since that ridership historically benefited most from the commuter trip. Since the 1970s, automobile ownership has continued to rise, but transit has stopped declining in raw numbers because of several possible reasons. Among them are continued population increases, State and Federal programs designed to increase use of public transportation, higher parking and congestion costs in some metropolitan areas, and greater environmental concerns.

Interestingly, it appears that the large changes in the trends—between 1907 and 1950—were driven strongly by technological, social, economic, and demographic changes as opposed to public policy initiatives alone. Technological developments, such as innovation in rubber-tired vehicles that enabled the bus to take market share away from the streetcar in the 1920s, had more of an impact on ridership trends than later public policy initiatives, such as encouraging the use of transit instead of automobiles in the 1990s.

There are, of course, instances where public policy initiatives have had a marked influence, such as the combination of vehicle, roadway, and driver improvements that have decreased fatality rates for automobile passengers during the past few decades.

Looking forward is much more difficult than looking backward. For example, if someone in the year 1925 had been looking ahead based on previous data, what might he or she have predicted over the next two decades? What trends would a national-level forecaster have identified correctly? What trends might have remained hidden?

Comparison of Predicted and Actual Changes Assuming a 1925 Base Year



Suppose a forecaster in 1925 used historical data available at that time to predict how population and the use of streetcar/light rail, rapid rail transit, bus, and automobiles would change from 1925 to 1950. The figure on the left shows the forecaster's predictions for the year 1950. The figure on the right shows what actually happened in 1950. A comparison of the two figures demonstrates that even national-level predictions may be difficult to get right. For example, the trend line forecast for automobiles predicted that there would be six times the number of automobiles in 1950 as there was in 1925. But in reality, the 1950 figure was only twice the 1925 level.

With only the historical base from 1907 to 1925 to draw from, the 1925 forecaster probably would have predicted rapid growth in three of the four transportation modes: bus ridership, automobile ownership, and rapid rail transit use, all outpacing population growth. The forecaster would have expected population to continue rising but not as quickly as those three modes. An astute 1925 forecaster possibly would have expected streetcar ridership to drop, given that stakeholders in the transit industry were becoming more receptive toward the bus as a new technology, although discerning the trend of buses taking market share from streetcars was more difficult in 1925 than in later years. Less knowledgeable forecasters might have thought the drop in streetcar ridership since 1920 was merely an aberration.

"Long-range plans should be updated regularly to evolve as new information becomes available. In that way, we are not locked onto a rigid conception of the future."

Taking these five transportation trends in turn, a perceptive forecaster in 1925 might have called half of them accurately. The forecaster likely would have predicted the 1950 population just about perfectly, with the past indications of national population trends being an accurate predictor of the present.

High marks also would have been awarded for the prediction of increased bus ridership, but the accuracy stems more from chance than anything else. Although the forecaster probably could not have foreseen the Great Depression, the dominance of bus over trolley transit, or World War II rationing—all of which would affect bus ridership—these factors would have combined to make the forecaster's estimate of bus ridership seem respectable. In short, the historical trend *coincidentally* would give a good prediction in this particular case.

For the automobile, the high value predicted for 1950—five times the level in 1925—would come true eventually—but not until 1975. The prediction for electric trolley ridership also might have been in the right direction, but the 1950 prediction would have been higher than it should have been. Finally, the rapid rail transit ridership would have proven the most difficult to predict. Increased urbanization and the early growth of rapid rail transit prior to 1925 might have suggested continued growth in this industry by 1950; however, rapid rail actually declined.

In fact, it is difficult to pick any 25-year horizon and be guaranteed success in predicting all five trends accurately, using only data available up to that point in time, with a possible exception being the period from 1975 to 2000. This problem is exacerbated when smaller area forecasts must be made for counties or census tracts, where it is much easier to make forecasting errors. Realistically, of course, more complex forecasting models can be developed to keep estimates "in check." The number of automobiles can be constrained to a reasonable proportion of the population, for example, but predicting shifts such as the rapid rise in automobile ownership starting in 1945 is more difficult.

Looking ahead, planning officials may question how other technologies will develop. Will new technologies proliferate in an exponential manner as in the case of wireless phone usage, or will growth be steadier and more linear, comparable to that of alternative fueled vehicles?

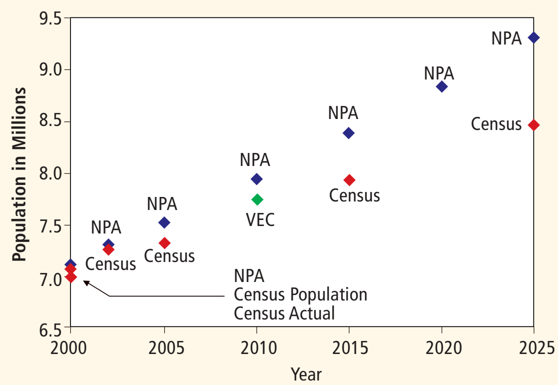
Conclusions

Long-range transportation plans are necessarily based on the assumption that historical data, combined in some cases with an understanding of the transportation environment, can be used to predict the environment over some planning horizon, say, a quarter century. This is probably accurate for statewide population totals and may be accurate for employment and personal income growth within large geographical subareas.

Yet historical examples of changes in behavior, such as the mode of transportation chosen by passengers or the number of miles driven, also are affected by significant technological or social changes. And it is difficult to predict key technological and social developments decades into the future, such as the innovations in the rubber-tired bus over the streetcar during the 1920s, World War II during the 1940s, the oil embargo of the 1970s, or the rise in personal incomes in the 1990s. In a similar vein, it is not yet clear whether technologies, such as hybrid vehicles, or social movements, such as telecommuting, will see the rate of market penetration deviate from recent trends.

Other researchers also have noted the challenges to making predictions. In *A Guide to Smart Growth: Shattering Myths, Providing Solutions*, Jane Shaw and Ronald Utt, for example, note that in the 1920s, it would have been difficult to predict 80 years later that less than 2 percent of the U.S. population would work in agriculture. In fact, after finding significant differences in model forecasts of transportation and land use impacts, in the article "Comparisons from Sacramento Model Test Bed" in the *Transportation Research Record* series, the authors call 25-year forecasting a "bit of a fool's

Virginia Population Projections to 2025 From Different Data Sources



The figure shows statewide population estimates for Virginia derived from three sources: U.S. Census Bureau (Census), NPA Data Sources, Inc. (NPA), and the Virginia Employment Commission (VEC). In the short term, the estimates converge and are relatively close, falling between 7.0 million and 7.1 million in 2000 and between 7.5 million (VEC) and 7.9 million (NPA) in 2010. By 2025, however, the estimates are further apart: nearly 8.5 million (Census) versus 9.25 million (NPA). The variation in these estimates illustrates some of the uncertainty in making projections. For example, depending on the forecast, there can be a difference of nearly 1 million people when projecting the State's population 25 years into the future. *Source: VTRC.*

game." They suggest that truly prescient forecasters, if they exist, would invest in real estate speculation rather than urban planning.

The challenges, do, however, suggest two options to improve long-range plans. The first is to point out explicitly that not all trends can be forecast equally well. Some key trends, such as population, may be relatively feasible to predict, whereas others, such as changes in telecommuting, are more difficult.

One way to do improved long-range plans is to present estimates with ranges, such as population projections for Virginia from different data sources. The purpose of this approach is to demonstrate the disparity in forecasts from different but credible sources, as opposed to portraying the "most" accurate forecast. Another alternative to address the uncertainty, according to Tom Gillaspy of the State Demographic Center in Minnesota, is to perform an analysis using scenarios to examine how changes in key variables will affect a prediction.

"Since the size of the labor force in Minnesota is a function of two factors, future migration rates and future participation rates, we can obtain four different sets of predictions for the labor force in 2030," he says. "They include the combinations of low migration and participation, low migration and high participation, high migration and low participation, and high migration and high participation."

The second option for improving long-range plans is to tie the recommendations explicitly to the confidence that the planner has in the underlying trends. Suppose a multimodal plan suggests targeting resources toward providing greater travel choices because of expected increases in the proportion of the population aged 65 and older. A planner could ask, therefore, how sure are we that the State will continue to mirror national trends that show an increase in drivers over age 65, and to what extent should we assume that the behavior of this population will be similar to persons in that category today?

One answer is to review relevant literature. In the 1997 report *Societal Trends: The Aging Baby Boom and Women's Increased Independence*, for example, prepared on behalf of the Federal Highway Administration, Daphne Spain suggests that in 2030 women drivers age 75 and over may drive almost three times as many miles as women in that category at present.

Neither recommendation is a panacea. Given the desire to make transportation plans more transparent rather than more complex, the decision to add detail to a plan in the form of statements about uncertainty should not be taken lightly. "An important facet of transportation plans," says Louis Tognacci, senior planner at the Arizona DOT, "is that they distill a few basic concepts that can be communicated to a wide audience of nonspecialists. Thus, presenting a range instead of a point estimate may add unnecessary complexity."

Ranges, however, represent a feasible starting point for making long-range plans more representative of what is currently understood regarding the future.

"Our long-range planning provides a context that assists in guiding current decisionmaking," Tognacci adds. "Long-range plans should be updated regularly to evolve as new information becomes available. In that way, we are not locked onto a rigid conception of the future."

Scenario Planning: A Framework for Developing a Shared Vision for the Future

One answer to more accurate long-range planning might be scenario planning—an analytical tool that can help elected officials, the public, and transportation professionals prepare for what lies ahead. By considering the various factors that will shape the future, scenario planning can help inform and involve the public, ideally to facilitate consensus on how to deal with growth, accommodate future transportation needs, ensure a quality environment, and provide for an aging population.

Scenario planning provides a framework for developing a shared vision for the future by analyzing various forces that affect growth, such as health, transportation, economic development, environment, and land use. Scenario planning, which can be done at the statewide level or for metropolitan areas, tests various future alternatives that meet State and community needs. A defining characteristic of scenario planning is that it actively involves the public, the business community, and elected officials on a broad scale, educating them about growth trends and tradeoffs, and incorporating their values and feedback into future plans.

Scenario planning expands upon traditional planning techniques by focusing on major forces or drivers that have the potential to affect the future. By developing scenarios to tell a story of the future, planners are better able to recognize these forces and determine what planning activities can be done today and can be adapted in the future. Scenario planning is not intended to replace traditional planning practices. It is a process that can be applied to recognize the range of outcomes in the future, beyond what traditional planning can create.

A number of jurisdictions have used scenario planning successfully. To encourage others, FHWA is helping to identify opportunities for the use of scenario planning and providing technical assistance. FHWA is reaching out to FHWA divisions to work with their State DOTs and MPOs to explore specific actions to help improve the planning process using scenario planning tools. *For more information, contact Sherry B. Ways, Transportation Planner, FHWA Office of Planning at 202–366–1587 or e-mail sherry.ways@fhwa.dot.gov.*

—Sherry B. Ways

John S. Miller, Ph.D., P.E. is a research scientist with VTRC.

References are available in the online version of PUBLIC ROADS. *For more information, contact john.miller@virginiadot.org or access the trends report at http://virginiadot.org/vtrc/main/online_reports/pdf/03-tar5.pdf. For information on Virginia's 2025 plan, see www.sotrans.state.va.us/VTrans/home.htm.*

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Testing Truncated Domes

Accessibility guidelines for the disabled require detectable warnings on all curb ramps. Here's how some States are getting the job done right.

by Mark Chandler

Intersections that permit vehicles and pedestrians to interact are complex environments, especially for people who are blind or visually impaired. For safe and independent travel, persons with limited or no vision depend on environmental cues such as curbs, texture changes underfoot, ambient sounds, and physical elements that can be sensed by a cane. People with low vision also rely on color contrast as a navigational aid.

The Americans with Disabilities Act (ADA), passed in 1990, required the establishment of design criteria for building and altering commercial and public facilities, including sidewalks and curb ramps. In 1991, the U.S. Department of Transportation (USDOT) and the U.S. Department of Justice (USDOJ) developed a set of regulations for new construction and alterations. The regulations include standards that reference the *ADA Accessibility Guidelines for Buildings and Facilities* (ADAAG), developed by the U.S. Access Board—an independent Federal agency devoted to accessibility for people with disabilities. The guidelines require the installation of *detectable warnings* on sidewalks, street crossings and curb ramps, hazardous vehicular ways, and transit platform edges.

The guidelines define a detectable warning as "a standardized surface feature built in or applied to walking surfaces or other elements to warn visually impaired people of hazards on a circulation path." Detectable warnings are texturally unique and standardized features, intended to function much like stop signs. The warning alerts visually impaired pedestrians to the presence of hazards in the line of travel, indicating that they should stop and determine the nature of the hazard before proceeding further.

Since 1991, truncated domes have been the standard design requirement for detectable warnings on curb ramps and at flush transitions from sidewalks to street crossings. The U.S. Access Board temporarily suspended the standard in 1994 but allowed the suspension to expire in 2001, reestablishing the mandate.

Texas DOT

Members of the Public Rights-of-Way Access Advisory Committee evaluate a retrofit installation of truncated domes on a curb ramp in Portland, OR.

The small, flattened domes provide a surface that is distinguishable underfoot and by cane, and they are closely spaced so that pedestrians can maintain stability. In addition, the color of the domes contrasts with the surrounding pedestrian ramp to provide a cue for low-vision persons that a transition from the pedestrian area to the vehicular area is forthcoming.

The ADAAG requires that municipalities and States install truncated dome surfaces on all new curb ramps and on any projects involving alterations to existing ramps. "The lack of curb ramps and noncompliance with design standards for these facilities constitute the greatest number of ADA complaints in the pedestrian environment," says Associate Administrator for Civil Rights Frederick Isler of the Federal Highway Administration (FHWA). "There continues to be a misconception that detectable warnings are not a requirement, but they are." (See "Truncated Warning Domes and the Americans with Disabilities Act" on this page.)

Truncated Warning Domes and the Americans with Disabilities Act

The Americans with Disabilities Act (ADA) is a landmark law that prohibits discrimination in employment, State and local government services, transportation, public accommodations, commercial facilities, and telecommunications. FHWA is obligated to enforce the requirements, and State and local governments are required to apply the minimum design standards when constructing and altering pedestrian facilities, though the agency encourages exceeding the minimum standards wherever possible.

In 1994, the U.S. Access Board temporarily suspended the requirements (except those applicable to boarding platforms at transit facilities) due to concerns about the technical specifications, the availability of compliant products, and maintenance issues such as snow and ice removal. The suspension expired on July 26, 2001. Now the requirements for detectable warnings at curb ramps are again part of the enforceable standards. When constructing and altering pedestrian facilities, State and local governments are required to install truncated domes as detectable warnings to identify the boundary between the sidewalk and street for persons with visual disabilities.

To view the complete rule, visit www.access-board.gov/adaag/html/adaag.htm.

Timeline

1990—Congress passes the ADA and assigns USDOJ and USDOT to develop implementation regulations and the U.S. Access Board to develop guidelines for facilities and vehicles to serve as standards for new construction and alterations.

1991—USDOJ publishes implementation regulations under Title II (governing State and local governments) and Title III (governing the private sector), and USDOT publishes Title II regulations for transportation services. U.S. Access Board publishes the ADAAG, which are facility and vehicle guidelines that are referenced as standards for new construction and alterations in Title II and Title III. ADAAG requires detectable warnings on the full surface of curb ramps.

1994—USDOJ, USDOT, and U.S. Access Board impose temporary suspension on requirement for detectable warnings.

1999—U.S. Access Board forms Public Rights-of-Way Access Advisory Committee (PROWAAC) to recommend accessibility provisions to modify ADAAG to be more specific to sidewalks and streets.

2001—PROWAAC delivers its recommendations in a report at the Transportation Research Board annual meeting. Recommendations include changes to specifications for detectable warnings in ADAAG, such as the range of dome dimensions, setback from the curbline, and change from full ramp length to 61 centimeters (24 inches) of material.
—Temporary suspension expires.

2002—FHWA issues a memorandum to field staff noting requirements for detectable warnings.
—U.S. Access Board publishes draft guidelines for public rights-of-way that include changes to detectable warning requirements recommended by PROWAAC.

Future—Draft guidelines for public rights-of-way will next proceed to a Notice of Proposed Rulemaking and a Final Rule. Several administrative steps then must be taken before the guidelines can become enforceable standards. Until then, the current (1991) standards remain legal requirements. However, USDOT and the U.S. Access Board encourage States to use the draft provisions for detectable warnings as an equivalent facilitation until the rulemaking process is completed.

Defining Truncated Domes

According to the U.S. Access Board, research conducted in the 1980s indicated that the truncated dome is the most effective system for providing a distinctive pattern detectable by cane and underfoot. The research showed that other designs, such as grooves, striations, and exposed aggregate, are not detectable in the sidewalk and roadway environment because of similarities to other surface textures and defects.

Warnings should adjoin or abut the hazard to signal the impending change and extend beyond the average stride length so a person can detect, understand, and react to the warning before encountering the hazard.

Truncated warning domes typically fall into one of three categories: inset, glued, or stamped, depending in part on whether the project involves new construction or a retrofit. Inset products are those that are pressed into fresh concrete or recessed into the cutout portion of an existing sidewalk, including ceramic or concrete tiles and pavers (landscaping bricks). Glued-on products are those that involve applying flexible mats of domes onto an existing sidewalk using an adhesive. Stamped concrete systems involve imparting the dome texture on a fresh concrete surface using either rigid or flexible stamping tools, typically made of rubber or polyurethane.

In terms of compliance, Peter Kemp, with the Technology Advancement Unit at the Wisconsin Department of Transportation (WisDOT), stresses the importance of differentiating between the 1991 regulation standards, ADAAG, and the subsequent draft guidelines for public rights-of-way. "The draft guidelines now are underway for a new rulemaking on right-of-way access," he says, "but it may be several years before the draft guidelines become regulations. In the interim, the U.S. Access Board has given individual State departments of transportation guidance on how to implement the draft guidelines and meet the 1991 standard."

Currently, the draft guidelines for public rights-of-way, published in June 2002, describe detectable warnings as a surface of truncated domes arranged in a square grid pattern. The domes need to have a base diameter of 23 to 36 millimeters (0.9 to 1.4 inches), a top diameter of 50 to 65 percent of the base diameter,

Duane Sippola

One worker uses a rubber mallet to sink an inset tile product into a new curb ramp in Madison, WI, while another smoothes the fresh concrete.

and a height of 5 millimeters (0.2 inch). Dome center-to-center spacing is allowed in the range of 41 to 61 millimeters (1.6 and 2.4 inches) and a base-to-base spacing of at least 16 millimeters (0.65 inch), measured between the most adjacent domes on the square grid. Detectable warnings also need to contrast visually with adjoining surfaces, either light-on-dark or dark-on-light. The surface of the detectable warnings must be 61 centimeters (24 inches) by the width of the curb ramp.

Since 2001, a number of municipalities, States, and other organizations have initiated product trials to evaluate the truncated warning dome systems available on the market. Highlights from research in Wisconsin, New Hampshire, and Texas offer insights on selecting the most effective products.

Wisconsin Tests Domes For Winter Wear

In 2002, responding to the reenacted regulation requiring truncated domes, WisDOT partnered with FHWA and the city of Madison to conduct a study of products on the market.

"We wanted to ensure that the methods and materials we chose would comply with the ADA rule and provide the lasting performance we wanted to see on our projects," says WisDOT's Kemp. "When we went looking for information about our options, we noticed a lack of good baseline data on what works as far as aesthetics, durability, color retention, and slip resistance. So we chose to do a limited study to identify products and improve our confidence level."

WisDOT selected the products to represent a cross section of the systems currently available. Installations were either cast in place for new sidewalks or retrofits to existing facilities. Retrofitted products included materials that were glued on, either in sheet form or applied individually to the surface of the sidewalk. The department evaluated eight products representing six manufacturers.

Staff from WisDOT and Madison's engineering division installed truncated warning domes on 44 ramps at 11 sites throughout the city. The sites were selected based on sidewalk condition, ramp configuration, and the possibility of incorporating installations into existing contracts for upgrading sidewalks. The installations began in fall 2002, and the team evaluated the performance of each product through the winter and following spring. In November 2003, WisDOT published its final report, *Truncated Warning Dome Systems for Handicap Access Ramps* (WI-04-03).

According to Kemp, the team has approved inset systems only, based on criteria such as ease of construction, consistency in quality, aesthetic quality, durability, and color retention. "Insets take minimal additional labor to install," he says, "You don't have to grind the sidewalk, so you have a more consistent look. Some of the glued-on products left adhesive along the edges. One product was installed up to 0.5 inch [1.27 centimeters] above the existing sidewalk."

An additional aspect of the product trials in Wisconsin was a study of color contrasts. In 2000, the U.S. Access Board published *Detectable Warnings: Synthesis of U.S. and International Practice*, a report indicating that "safety yellow is a color that is standardized for use as a warning in the pedestrian-highway environment." A retired technical advisor to Madison's engineering division, Duane Sippola, who has more than 30 years experience working with tactile cues for curb ramps, suggested bringing in staff members from the Wisconsin Council of the Blind to evaluate the color of the products. The objective was to determine which colors were best for visually impaired persons and at what distance they start to pick up the contrast of a dome-patterned ramp.

"Designers and public officials often are drawn to a variety of colors for aesthetic reasons, but we need to remember that our goal is to protect pedestrians," Sippola says. "In our tests, we found that yellow stands out really well for partially sighted pedestrians. Yellow and white could be seen at the farthest distances, in most cases, the width of a residential street, 32 to 45 feet [9 to 14 meters]. It seems that low-vision persons do notice the yellow color on signposts and curbs. Since all crosswalk lines are painted white, it seems to make sense that domed ramps should be yellow to provide the necessary contrast."

During the study, Sippola borrowed from the Wisconsin Council of the Blind a set of low-vision goggles simulating 20/200 vision. He then took digital photos through the goggles at distances ranging from 12.5 meters (41 feet) to 0.75 meter (2.5 feet) to illustrate the importance of color and contrast in recognizing ramp treatments. "It's hard for sighted people to imagine what visually impaired folks experience," Sippola says. "This experiment really points out the effectiveness of the yellow color."

To comply with ADA guidelines, WisDOT selected yellow and white as the standard colors for domed ramps. The agency implemented the new standard for truncated warning domes starting in July 2003. Further, WisDOT developed detailed draw-

To illustrate the importance of color and contrast in ramp treatments, researchers from WisDOT and the city of Madison took digital photographs through low-vision goggles at distances of (left) approximately 9.8 meters (32 feet) and (right) 1.5 meters (5 feet). *Photos: Duane Sippola.*

ings, construction notes, specifications, and an approved product list, and will continue evaluating new products, including stamped concrete and precast masonry panels.

For more information, contact Peter Kemp at 608–246–7953 or peter.kemp@dot.state.wi.us.

New Hampshire Builds Test Sidewalk

In December 2002, the New Hampshire DOT initiated a study to document the ease of installation and durability of eight truncated warning dome systems under winter maintenance and weather conditions, including plowing and surface deicing treatments.

"We had very little information on what products would work best in our region," says Assistant Research Engineer Denis Boisvert, with the New Hampshire DOT. "Manufacturers typically don't provide data on the performance of their products in the winter or under the plow. They test durability through wear resistance, using 60-grit sandpaper under a 1-kilogram [2.2-pound] load, which might simulate pedestrian traffic well, but it's not appropriate for assessing the wear from a plow."

Along Hazen Drive in Concord, NH, the department constructed a 70-meter (229-foot)-long sidewalk consisting of individual test sections to accommodate each dome system. Five installations required cutting recessed surfaces, one involved stamping the domes directly onto a fresh concrete surface, and the other three featured typical sidewalks for surface-applied retrofits. The shop-fabricated test sections were transported to the site by flatbed truck and trailer, and then lifted into place by a truck-mounted crane in February 2003.

The city of Concord plowed and treated the test sections as part of its regular maintenance routine for municipal sidewalks, using a 1.5-meter (5-foot)-wide, four-wheel drive vehicle with a hydraulically angled plow blade.

Staff from the New Hampshire DOT documented the installation and evaluated the performance of the test sections during the first winter through 20 plowing cycles. The first two cycles involved natural snowfall, but since the test sections were installed in late February, the researchers were concerned whether enough storms would occur to constitute a satisfactory number of plowing cycles. Therefore, the department planned to generate as many artificial snowfall cycles as possible in 1 day, piling snow on the test sections using a front-end loader, followed by repeated removal by the city's plow.

Like Wisconsin, New Hampshire found inset systems to hold the most promise. "We identified two inset products that we will apply to upcoming construction projects," Boisvert says. "They are the most durable of the compliant products we tested. We are monitoring the sidewalk for a second season for long-term performance."

The stamped product was the least attractive due to deformities of the domes and background mat that resulted in dimensional noncompliance (in terms of height or diameter) with the guidelines. "The domes showed substantial damage and wear after the initial testing of 20 plow passes," Boisvert says.

Boisvert and his colleagues note that testing revealed two types of failures. "The domes themselves wear quickly, or the entire system is torn off or peels off, particularly surface-applied products," he says. "The plow catches the edge and tears the product or rolls it off the surface. The domes that receive the worst wear are the first row. Once the plow is on top of the dome matrix, the wear is less. But after a few seasons, they too may be in tough shape. Even with the better performers, this is an area for further research to extend product life. If the products were recessed even more, so the domes were flush with the top of the sidewalk, we might not see as much damage."

The department published a final report, *Durability of Truncated Dome Systems* (FHWA-NH-RD-MPS2002-2), in April 2003. For more

NHDOT researchers used this plow to evaluate the durability of various truncated warning dome systems during snow removal. Damaged domes are visible in the foreground.

NHDOT

NHDOT

After 20 plow passes, this recessed inset dome system was among the most durable of those tested by NHDOT.

NHDOT

Three plow passes destroyed this surface-applied product.

information, contact Denis M. Boisvert at 603–271–3151 or dboisvert@dot.state.nh.us.

Texas Domes Weather the Heat

While durability in cold weather and under snow removal is a primary concern in the north, in the warmer States, like Texas, the effects of the sun's heat represent the biggest challenge to durability. Since 2002, the Texas DOT has used brick pavers with truncated domes on several hundred projects, with considerable success.

"We were fortunate to benefit from lessons learned by the city of Austin as they experimented with various products in the late 1990s," says Elizabeth Hilton, director of plan development with the Texas DOT Design Division. "Some engineers tried using stamped concrete to create the truncated domes, but these were difficult to construct properly and tended to break off easily. The only problem we have had with the brick pavers is achieving a flat surface on the curb ramp. The city advised us that when they placed the pavers on a sand bed, as is typical with landscaping bricks, the sand washed out due to the slope of the curb ramp, resulting in an irregular surface. Therefore, our placement detail requires that contractors place pavers on a mortar bed."

To expand the options, the department recently initiated an informal study to identify additional products for use in both new installations and retrofits. The purpose, according to Hilton, is to identify an array of acceptable products that the department can choose from, ultimately enhancing competitive bidding among manufacturers.

"We offered vendors the chance to install their products at our Riverside complex in Austin," she says. "We are evaluating how well the domes stay on the surface and how the products weather, particularly in the Texas heat. Our main concern is with adhesive products coming unglued in the heat. Durability of the color contrast, or the light reflective value, also is a concern."

Although the evaluation is ongoing, Hilton says that, so far, most of the products have yielded acceptable results. In fact, the department has begun allowing use of the products on the State highway system.

For more information, contact Elizabeth Hilton at 512–416–2689 or ehilton@dot.state.tx.us.

Meeting the Challenge

According to the U.S. Access Board's report, complex traffic operations, including actuated signals and right turns on red, have made it increasingly difficult for visually impaired persons to analyze the roadway environment using vehicular sound. High traffic volumes and ambient noise often mask the sounds of vehicles starting and stopping. In addition, the trend toward more aggressive driving has reduced the likelihood that drivers will stop for pedestrians in crosswalks at unsignalized intersections. Now, more than ever, efforts like truncated warning domes are essential to ensuring safety and access for visually impaired persons.

"Education is critical for engineers to know why the domes are needed so they can locate them in the correct place," says Hilton from the Texas DOT. "Our solution is to train engineers in the department on curb ramp design, including the

Notes on the Guidelines

On July 23, 2004, the U.S. Access Board published new guidelines for accessible design (www.access-board.gov/ada-aba.htm) under the Americans with Disabilities Act (ADA) and Architectural Barriers Act (ABA). Although the Board's work is done, the new rules will not be enforceable until the Federal rulemaking agencies complete the administrative process necessary to adopt the new guidelines as standards (the U.S. Department of Justice and USDOT under the ADA, and the General Services Administration, the U.S. Department of Defense, U.S. Department of Housing and Urban Development, and U.S. Postal Services under the ABA). In the meantime—the U.S. Department of Justice (USDOJ) estimates that the process will take a year or two—current standards remain in effect.

Alert readers will note that the ADA/ABA accessibility guidelines do not include scoping for detectable warnings at curb ramps and blended transitions but only for transit platforms (technical provisions are included in Section 705). That is because the board decided to address detectable warnings in the rights-of-way rulemaking process, which has been separated from the current rulemaking for buildings and facilities. Many engineers who commented on the rights-of-way draft published in June 2002 (www.access-board.gov/rowdraft.htm) recommended a separate, stand-alone standard. The new document will use industry terms and measures to facilitate implementation. Both regulations are expected to become effective about the same time, so there will be no gap in regulation for detectable warnings.

When the public rights-of-way guidelines are complete, USDOT has indicated its intent to adopt them as its standard under Section 504 of the Rehabilitation Act of 1973 for agencies receiving Federal funding. Note that this covers all programs of any State DOT that receives highway aid or other Federal money, and any local programs funded even in part by State DOT or Federal monies. USDOJ will follow after its lengthier rulemaking process.

For More Information on Truncated Warning Domes

American Association of State Highway and Transportation Officials
AASHTO Product Evaluation List
http://apel.transportation.org/programs/apel/products/site.nsf

Federal Highway Administration
Designing Sidewalks and Trails for Access: Part I of II: Review of Existing Guidelines and Practices
http://safety.fhwa.dot.gov/fourthlevel/pdf/ada.pdf

New Hampshire DOT
Durability of Truncated Dome Systems (FHWA-NH-RD-MPS2002-2)
www.nh.gov/dot/materialsandresearch/research/projectlist.htm

Wisconsin DOT
Truncated Warning Dome Systems for Handicap Access Ramps (WI-04-03)
www.dot.wisconsin.gov/library/research/docs/finalreports/tau-finalreports/truncatedwarningdomes.pdf

Vermont Transportation Agency
Report on Installation of Truncated Dome Products in Burlington, Vermont
www.aot.state.vt.us/progdev/Documents/LTF/TruncatedDomeInstallationReport/TruncatedDomeInstallationReport.pdf

U.S. Access Board
ADA Accessibility Guidelines for Buildings and Facilities (ADAAG)
www.access-board.gov/adaag/html/adaag.htm

Building a True Community: Final Report Public Rights-of-Way Access Advisory Committee (January 2001)
www.access-board.gov/prowac/commrept/index.htm

"Draft Guidelines for Accessible Public Rights-of-Way" (June 17, 2002)
www.access-board.gov/rowdraft.htm

"ADAAG Requirements for Detectable Warnings: March 2003"
www.access-board.gov/adaag/dws/update.htm

Detectable Warnings: Synthesis of U.S. and International Practice (2000)
www.access-board.gov/publications/DW%20Synthesis/report.htm

Texas DOT

Landscape pavers with truncated domes, like those shown here on a sidewalk in Austin, TX, have been used on many projects in Austin and elsewhere in Texas.

appropriate use of truncated domes."

In addition to educating in-house staff, Dennis Cannon of the U.S. Access Board notes that government staff members need to communicate the requirement for truncated warning domes to the contractors who install curb ramps. "Every curb ramp eventually will need to be replaced," Cannon adds, "whether because of wear and tear, installation of utility lines beneath the sidewalk, or a widening project. The key is to survey all curb ramps, locate those that are in bad shape, and then rank them from worst to best to prioritize scheduling replacements. It's often best to start with the downtown or the areas that are most traveled."

Ultimately, it is up to State and local agencies to determine which compliant products will work best in their environments and when to install them, but resources exist to help engineers, designers, and decisionmakers make the most effective choice. The challenge is to make *everyone's* accessible route a safe one.

Mark Chandler, PE, CMfgE, is the technology transfer and quality engineer with the FHWA Wisconsin Division. Chandler has an undergraduate degree in geoengineering and a master's in manufacturing systems engineering, with a concentration on quality. He is a candidate in the Indiana State University distance Ph.D. program in technology management, with a specialization in quality systems.

The American Association of State Highway and Transportation Officials funded a project through the National Cooperative Highway Research Program (NCHRP) that will gather and compile research and evaluation data available from State DOTs on maintaining detectable warnings. The Texas Transportation Institute is performing the research, and a final report is expected in 2005. For more information, the NCHRP contact is Dr. Amir N. Hanna at ahanna@nas.edu.

For more information on truncated warning domes, contact Mark Chandler at 608-829-7514 or mark.chandler@fhwa.dot.gov.

Along the Road

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

Management and Administration

FHWA Administrator Urges Drivers To Make Work Zones Safer

Likening roads to the "offices" of highway workers, Federal Highway Administrator Mary E. Peters recently had her desk set up in the middle of an interchange on Interstate 95 in Springfield, VA, to demonstrate the dangers of unsafe driving habits in highway work zones. The event kicked off this year's National Work Zone Safety Awareness Week.

Fatalities in work zones increased nationwide by 53 percent between 1998 and 2002, according to data from the Federal Highway Administration (FHWA). Four out of five people killed were either drivers or passengers. Peters, however, notes that a combination of government safety programs and safe driving habits can significantly reduce the more than 52,000 injuries and fatalities that occur each year in highway work zones.

Solutions for creating safer work zones include using more durable pavements and "defensive" work zones—ones that provide better protection from motorists—and providing real-time information that enables travelers to plan alternative routes. Peters offered a number of tips for driving safely in work zones, reminding motorists to slow down, avoid tailgating, stay alert, and obey road crew flaggers and signs.

For more information, visit http://safety.fhwa.dot .gov/wzs/factsheet04.htm.

FHWA Administrator Mary E. Peters recently set up an "outdoor office" in the median of an interchange on I–95 in Springfield, VA, to kick off National Work Zone Safety Awareness Week.

Public Information and Information Exchange

USDOT 2003 Performance Report Rated Best in Government

USDOT's *Performance and Accountability Report* for fiscal year 2003 tied for first place as the best in government, according to an independent assessment by The Mercatus Center—an education, research, and outreach organization based at George Mason University in Arlington, VA. The organization rated USDOT's report, along with the U.S. Department of Labor's, as the Federal reports most effective in measuring the level of success in attaining major strategic goals.

Mercatus gave the report a rating of 16 out of a possible 20 points for "Transparency" because of its direct link on FHWA's home page and because of its overall readability. In the "Public Benefits" category, the report received a 15/20 for presenting results-oriented strategic goals and outcomes, and for demonstrating USDOT's impact on the public in spite of significant external factors impacting the agency's performance. The report attained its highest of the three category ratings—17/20—for "Leadership" by citing specific measures to remedy performance shortfalls and by extensively analyzing opportunities for improvement, even in areas where targets were met. Mercatus ranked USDOT's annual performance plan either first or second in every fiscal year since FY1999.

For more information, view USDOT's 2003 Performance and Accountability Report *at www.dot.gov /perfacc2003/index.html or the Mercatus report at www.mercatus.org.*

Discovery Science Channel Films at TFHRC

The Discovery Science Channel recently visited FHWA's Turner-Fairbank Highway Research Center (TFHRC) in McLean, VA, to film a show for its television series called *Techknowledge*. A segment called "Safe Highways," featured in the show "Driven by Design," showcases both the center's field research vehicle and its highway driving simulator.

The show, which aired on March 10 at 8:30 p.m., also featured segments of interviews with Joey Hartmann, a research structural engineer with TFHRC. Filmed at the facility's curved girder bridge, the interviews highlighted new developments in high-performance concrete. TFHRC's main part in the show, however, was an uninterrupted 5-minute segment featuring the Human Factors Field Research Vehicle. Joe Moyer, an engineering research psychologist at TFHRC, introduced the many functions of the vehicle. A self-contained research laboratory, the vehicle supports highway safety and ITS research and has the capability of collecting driver performance measures, like acceleration/deceleration and eye movement. It also displays navigation, route guidance, and in-vehicle warnings.

Techknowledge is a new series that introduces groundbreaking research with the potential to alter day-to-day life significantly. The series is slated to showcase innovative technological advances, including an underwater airplane and a zero-energy home.

For more information, contact Nancy Singer at 202-366-4650.

Transportation Libraries Catalog Now Available Online

Coordinated by the National Transportation Library, the Transportation Libraries Catalog (TLCat) is now available online at http://ntl.bts.gov. TLCat enables users to search simultaneously the collections from multiple transportation libraries held in the Online Computer Library Center (OCLC). The catalog incorporates the collections of more than 20 significant libraries, including those in the Midwest Transportation Knowledge Network, Transportation Research Board, Northwestern University Transportation Library, and Harmer E. Davis Transportation Library at the University of California, Berkeley. Participation in TLCat is open to institutions that have transportation-specific libraries, the holdings of which must be cataloged in OCLC under a unique identifier.

TLCat users can query all available transportation libraries or limit their searches to government, university, or Midwest transportation libraries, searching by keyword, author, title, publication number, year of publication, or any combination of these criteria. Guest access is available at http://ntl.bts.gov.

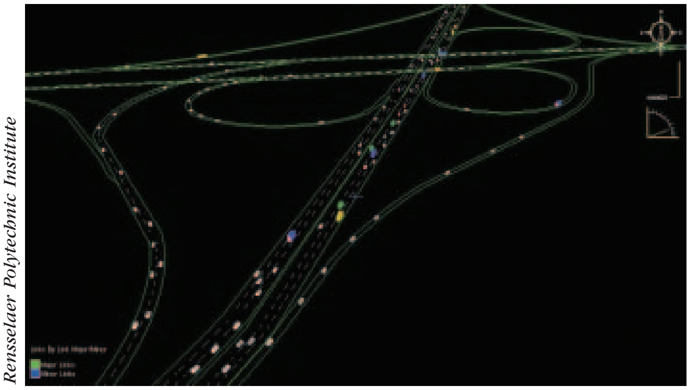
For more information, contact Nelda Bravo at nelda.bravo@bts.gov.

Technical News

Rensselaer Polytechnic Institute Helps Make "Smart Vehicles" Even Smarter

Today's "smart vehicles" may be getting a little smarter as a result of research currently underway at Rensselaer Polytechnic Institute in Troy, NY. Led by Dr. George List, professor and department chair of civil and environmental engineering, and Dr. William Wallace, professor of information systems and decision sciences, a research team is developing a system that collects real-time traffic data and uses the information to alert drivers about congested roadways, offering alternative routes to avoid problem areas.

The dynamic routing system, called Advanced Traveler Information System (ATIS), consists of a personal digital assistant device and a global positioning system (GPS) that work in tandem with a wireless computer network. The network collects and processes traffic data from the device and feeds the results to the driver through an electronic voice mechanism. The researchers feel that this innovative combination of data-gathering technology,



Rensselaer Polytechnic Institute

Rensselaer Polytechnic Institute soon will begin selecting a test group of volunteers to use the Advanced Traveler Information System (ATIS) in their cars late this summer. Researchers used microscopic simulation modeling tools, like the one shown here, to study traffic patterns and model traffic flow for the test bed network.

GPS technology, and navigational routing software ultimately will make travel safer and more efficient.

The researchers began testing the system with a group of 200 volunteers during the summer of 2004. The drivers commute each weekday morning to a location within a specified suburban test bed area in Rensselaer County, NY. The researchers chose the area because traffic volume varies significantly due to a combination of freeways and rural roads.

The ATIS project is funded by a $1.6 million grant from USDOT and the New York State DOT. The ATIS team is led by Rensselaer researchers but also includes representatives of other academic research institutions and other public and private organizations.

For more information, contact Mary Cimo at 518-276-6098 or cimom@rpi.edu.

Rensselaer Polytechnic Institute

Personnel

FHWA's Jerry DiMaggio Contributes to Major Civil Engineering Textbook

The Office of Bridge Technology's Senior Geotechnical Engineer Jerry DiMaggio had the distinguished honor of coauthoring a major section in the 5th edition of the internationally recognized *Standard Handbook for Civil Engineers*, recently published by McGraw-Hill. DiMaggio worked on Section 7, "Geotechnical Engineering," with Mohamad H. Hussein, from GRL Engineers, Inc. The handbook is used widely by practicing engineers and in engineering curricula at colleges and universities.

According to the publisher, the book covers systems design, community and regional planning, and the latest design methods for buildings, airports, highways, tunnels, and bridges. It also includes sections on construction equipment, construction management, materials, specifications, structural theory, geotechnical engineering, wood, concrete, steel design, and construction.

For more information, contact Jerry DiMaggio at 202-366-1569 or jerry.dimaggio@fhwa.dot.gov.

Communication Product Updates

Compiled by Zac Ellis of FHWA's Office of Research and Technology Services

Below are brief descriptions of products recently published online by the Federal Highway Administration's (FHWA) Office of Research, Development, and Technology. Some of the publications also may be available from the National Technical Information Service (NTIS). In some cases, limited copies are available from the Research and Technology (R&T) Product Distribution Center.

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

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703–605–6000
Toll-free number: 800–553–NTIS (6847)

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

R&T Product Distribution Center, HRTS-03
Federal Highway Administration
9701 Philadelphia Court, Unit Q
Lanham, MD 20706
Telephone: 301–577–0818
Fax: 301–577–1421

For more information on research and technology publications from FHWA, visit the Turner-Fairbank Highway Research Center's (TFHRC) Web site at www.tfhrc.gov, FHWA's Web site at www.fhwa.dot.gov, the National Transportation Library's Web site at http://ntl.bts.gov, or the OneDOT information network at http://dotlibrary.dot.gov.

Incremental Costs and Performance Benefits of Various Features of Concrete Pavements
Publication No. FHWA-HRT-04-044

This TechBrief presents a methodology for quickly assessing the relative costs and benefits of incorporating various design features into portland cement concrete (PCC) pavements. The methodology has been incorporated into an analytical software tool that pavement design engineers can use to investigate the cost-versus-performance tradeoffs associated with selecting different features during the PCC pavement design process. Although the software is not intended to provide absolute answers on the effects of different design features, it can provide insight into general performance and cost trends associated with using those features.

The document discusses why design features—including dowel bars, tied shoulders, and drainable bases—that can be added to PCC pavement designs to improve overall performance by increasing serviceability or extending service life also can sometimes increase the initial cost of the design significantly. Taking into account that current practices do not always consider the tradeoffs between performance benefits and costs, this publication points out that adding more features to the design may produce increasingly small performance gains while raising the final cost of the pavement structure.

A Review of Pedestrian Safety Research in The United States and Abroad
Publication No. FHWA-RD-03-042

This report provides an overview of research studies on pedestrian safety in the United States and in other countries. Readers will find information on pedestrian crash characteristics, measures of pedestrian exposure and hazard, and the effects of specific roadway features on pedestrian safety. Such features include crosswalks and alternative crossing treatments, signalization, signage, pedestrian refuge islands, provisions for pedestrians with disabilities, bus stop locations, school crossing measures, reflectorization and conspicuity, grade-separated crossings, traffic-calming measures, and sidewalks and paths. Educational and enforcement programs related to pedestrians also are discussed.

The report builds on two earlier reports. The most recent is *Synthesis of Safety Research: Pedestrians* (FHWA-SA-91-034), by C.V. Zegeer, published in August 1991. The earlier work is Chapter 16 from "Pedestrian Ways" by R.C. Pfefer, A. Sorton, J. Fegan, and M.J. Rosenbaum, published by FHWA in *Synthesis of Safety Research Related to Traffic Control and Roadway Elements* (from Volume 2, December 1982). The updated report includes results from numerous domestic and foreign studies on pedestrian safety—including those from Australia, Canada, the Netherlands, Sweden, and the United Kingdom—that are available online at www.walkinginfo.org/rd/international.htm.

Reporting Changes of Address

PUBLIC ROADS has two categories of subscribers. One includes the organizations and people who receive the magazine without charge, and 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, and the mailing list for this group is maintained by the Superintendent of Documents for the U.S. Government Printing Office.

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Internet Watch

by Keri A. Funderburg

FHWA's GIS Web Site Maps the Way for the Transportation Industry

In Orange County, CA, an area with a high rate of automobile usage, officials at the county transit agency are using a geographic information system (GIS) to provide detailed information on the area's demographic and land use characteristics to help the agency maximize its effectiveness and efficiency when planning transit services and operations. In Florida, the State department of transportation (DOT) is using GIS to streamline its efforts to identify and analyze the habitat of the black bear, a species important to the study of the highway system's impact on natural habitats in the area.

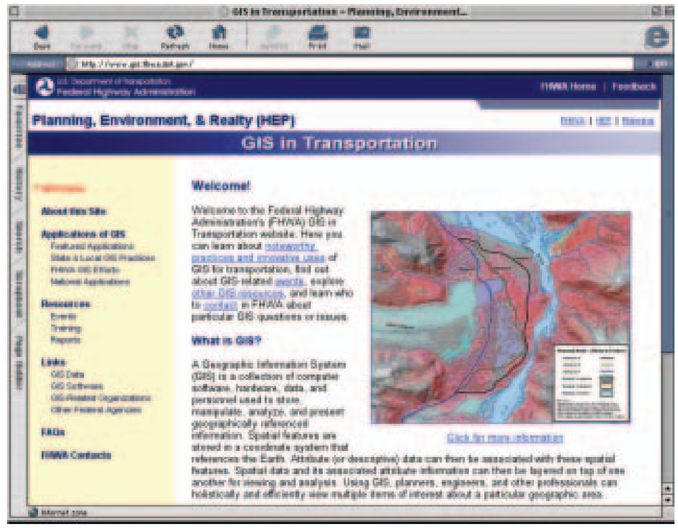
These and other transportation agencies across the Nation and at all levels of government, including the Federal Highway Administration (FHWA), are finding new ways to use GIS for transportation applications. A new Web site developed by FHWA's Office of Planning, Environment, and Realty now provides a one-stop shop where transportation professionals and the public can learn more about GIS resources. The "GIS in Transportation" Web site, accessible at www.gis.fhwa.dot.gov, highlights noteworthy practices and innovative uses of GIS in transportation projects.

"[Visitors] can read about different GIS-transportation activities occurring across the country," says Mark Sarmiento, a community planner at FHWA. "Transportation professionals can learn about upcoming GIS-related meetings, conferences, reports, and white papers—and publicize their own work. In addition, agencies in the initial stages of implementing a GIS can learn from the experiences of others."

Accessible Applications

The site is divided into several sections. A section called "Applications of GIS" includes information on notable or distinctive uses of GIS or applications that have contributed significantly to a State's transportation system or environmental review process. An interactive map enables users to find out about GIS applications at the State and local levels. The section also describes FHWA's use of the technology, including the Highway Performance Monitoring System Viewer, which enables users to map, view, and compare data on the extent, condition, performance, use, and operating characteristics of the Nation's highways. GIS applications at several other Federal agencies are available as well. The U.S. Environmental Protection Agency, for example, developed EnviroMapper™ to display comprehensive environmental data for the United States, such as water features and brownfield sites.

"One of the biggest features of the Web site is the searchable database of GIS applications," says Sarmiento. "Users can search the site for GIS transportation applications according to keyword, State, an area of interest (such as environment, planning, or transit) or by using a combination of options." Users also can submit information on their own GIS initiatives.



FHWA's "GIS in Transportation" Web site.

Resource Review

In the "Resources" section, users can learn about conferences, meetings, peer exchanges, and other upcoming events in the field of GIS for transportation. In the future, users also will be able to locate summaries of past events. This section features links to training opportunities around the country, such as GIS-related courses offered by the National Highway Institute and the U.S. Department of the Interior's National Park Service. In addition, users can download reports, including *Implementation of GIS-Based Highway Safety Analyses: Bridging the Gap* (FHWA-RD-01-039), an FHWA report that discusses the integration of GIS into safety-related analyses.

Helpful Links

The Web site also provides links to other GIS-related sites. From the "Links" section, users can access sites with downloadable data layers pertinent to transportation-oriented GIS and visit commercial vendors that offer applications for opening, reading, and manipulating spatial data. The links also point users to nongovernmental organizations and Federal agencies that conduct and sponsor GIS-related activities.

Other features include a list of FHWA contacts and frequently asked questions and answers that provide basic information about GIS applications.

"The transportation industry and the public both may benefit from the site," Sarmiento says, "[by learning] about the different ways that States and regional and local transportation agencies are using GIS to save time and money in the decisions they make and the projects they implement."

Keri A. Funderburg is a contributing editor for PUBLIC ROADS.

Training Update

NATIONAL HIGHWAY INSTITUTE

New Course Orients Federal Lands Employees And Customers

This artist's rendering of the promenade planned for Pennsylvania Avenue in front of the White House in Washington, DC, represents one of several projects that FLH currently is administering.

Since the passage of the Transportation Equity Act for the 21st Century (TEA-21) in 1998, the program for the Federal Highway Administration's (FHWA) Office of Federal Lands Highway (FLH) has nearly doubled and may continue to grow pending reauthorization of Federal transportation legislation. With this expansion, FLH is hiring more midcareer professionals who have excellent technical skills but often know little about how FLH operates. To meet the increasing demand for technical assistance and ensure that all new hires understand the division's processes, the National Highway Institute, with help from FLH and FHWA's Office of Professional Development, developed a 3-day course to introduce newly hired employees and others to FLH operations and regulations. NHI held a pilot version of the course in Denver, CO, in March 2004.

The goal of Federal Lands 101 (#310108A) is to explore how FLH functions, including how it administers programs, delivers projects, develops and transfers technology, and provides external training. According to Don Tuggle, director of program administration for FHWA's Eastern Federal Lands Highway Division, course participants are exposed to the full range of project management and procurement processes used at FLH, including design-build contracting and cost-plus-time bidding—two innovative techniques that reduce construction time by combining project responsibilities.

Several aspects of FLH distinguish the division from other offices within FHWA. Its employees, for example, often perform hands-on design and construction work and operate through an FLH contracting office, whereas most FHWA offices focus on project oversight and do not perform these other functions. In addition, the large size of FLH's three branch offices, each comprising 200 or more employees versus only 20 to 50 in FHWA's Federal-aid division offices, requires that the FLH offices operate under a more complex organizational structure. "The FLH structure really constitutes a separate business line within FHWA," Tuggle says.

Prior to taking the course, participants typically have little experience in evaluating environmental impacts, financing transportation projects, or otherwise understanding "the things you don't learn in engineering school," Tuggle says. Although most new employees usually have considerable engineering experience, many need to learn more about transportation policy and procedures and other Federal regulations before administering projects.

Upon completing the course, participants will be able to identify the role and authority of FLH within FHWA and describe the distinctive characteristics of the division's customers and programs. They also will develop a greater understanding of the processes and resources that the office uses to deliver projects and conduct business and how FLH interacts with the Federal-aid division offices in each State.

The course will benefit employees in all positions and grades within FLH, workers within FHWA's Federal-aid offices—particularly new hires and employees from other Federal offices that are affected by FLH work, such as the U.S. Department of the Interior's Bureau of Land Management. Most important, the course orients direct hires or employees who join FLH in a midlevel position, who need to learn the culture and procedures of the office quickly to be effective.

"FLH has a large percentage of direct hires," says Tuggle. "We see a critical need to get these new employees educated on the organization as quickly as possible to maximize their individual effectiveness in addressing our organizational goals and workload. Our partner agencies also have expressed the desire to understand more about our organization, so we hope that Federal Lands 101 can help us address both of these needs."

For more information, visit NHI's Web site at www.nhi.fhwa.dot.gov/coursedesc.asp?coursenum=1134 or contact Don Tuggle at 703-404-6276 or donald.tuggle@fhwa.dot.gov. To learn more about transportation-related courses available from NHI, consult the course catalog at www.nhi.dot.gov or contact NHI at 4600 N. Fairfax Drive, Suite 800, Arlington, VA 22203; 703-235-0500 (phone); or 703-235-0593 (fax). For scheduling, contact Danielle Mathis-Lee at 703-235-0528 or danielle.mathis-lee@fhwa.dot.gov.

Conferences/Special Events Calendar

Date	Conference	Sponsor	Location	Contact
Nov 3-6 2004	2004 ARTBA Roadway Work Zone Safety Conference & Exhibition	American Road & Transportation Builders Association (ARTBA)	Baltimore, MD	Ashley Stow 202-289-4434 astow@artba.org www.artba.org/pdf/2004_workzone_conf_reg_brochure.pdf
Nov 15-16 2004	2004 Federal Aviation Administration Airports Land Conference	Federal Aviation Administration and International Right of Way Association	Chicago, IL	Rick Etter 202-267-8773 rick.etter@faa.dot.gov www.faa.gov
Nov 16-17 2004	7th Marine Transportation System Research and Technology Coordination Conference	Transportation Research Board (TRB)	Washington, DC	Joedy Cambridge 202-334-2167 jcambridge@nas.edu http://gulliver.trb.org/committees/cfp/AW000.pdf
Nov 18-20 2004	Research on Women's Issues in Transportation Conference	TRB	San Diego, CA	Hannah Whitney 202-624-5800 hannahw@aashto.org http://trb.org/conferences/women
Nov 30-Dec 2 2004	2004 Environmental Coordinators Conference	Texas Department of Transportation, Environmental Affairs Division	Austin, TX	Richard Goldsmith 512-416-2743 rgoldsmi@dot.state.tx.us www.dot.state.tx.us/env/events/2004ecc.htm
Dec 1-3 2004	Conference on Managing Travel for Planned Special Events	Intelligent Transportation Society of America	New Orleans, LA	Walter Kraft 212-465-5724 kraft@pbworld.com www.itsa.org/pse_conference.html
Jan 9-13 2005	84th TRB Annual Meeting	TRB	Minneapolis, MN	Julie Grazier 612-624-3044 jgrazier@cce.umn.edu http://gulliver.trb.org/conferences/2004-APT_Conf.pdf
Jan 24-26 2005	Geo-Frontiers	American Society of Civil Engineers	Austin, TX	Bob Gilbert 512-471-3688 bob_gilbert@mail.utexas.edu Sam Allen 512-263-2101 sallen@tri-env.com www.asce.org/conferences/geofrontiers05/index.cfm
Feb 27-Mar 5 2005	AASHTO Legislative Briefing	American Association of State Highway and Transportation Officials (AASHTO)	Arlington, VA	Janet Oakley 202-624-5800 joakley@aashto.org www.aashto.org
Mar 15-19 2005	CONEXPO-CON/AGG 2005	Association of Equipment Manufacturers, National Stone, Sand & Gravel Association, National Ready Mixed Concrete Association, and Associated General Contractors of America	Las Vegas, NV	Caroline Roberts 800-867-6060 croberts@conexpoconagg.com www.conexpoconagg.com
Mar 16-18 2005	Integral Abutments and Jointless Bridges Conference	Federal Highway Administration, U.S. Department of Transportation, West Virginia University, and West Virginia Department of Transportation	Baltimore, MD	Samer H. Petro 304-293-7608 samer.petro@mail.wvu.edu www.cemr.wvu.edu/cfc/conference/IAJB.pdf

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