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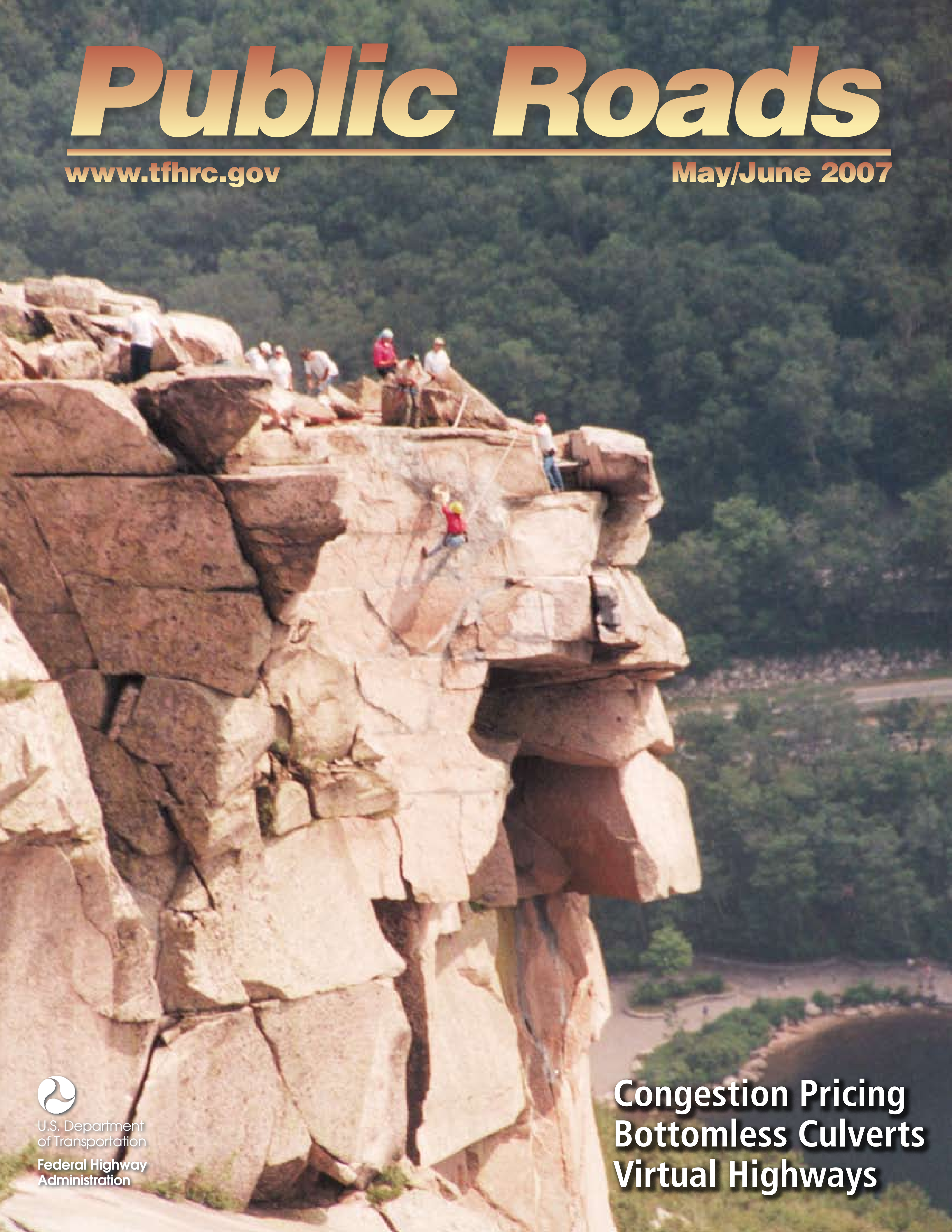

Congestion Pricing
Bottomless Culverts
Virtual Highways

U.S. Department
of Transportation
Federal Highway
Administration

Public Roads

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

Articles

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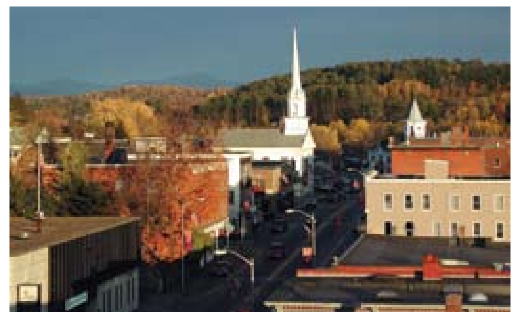

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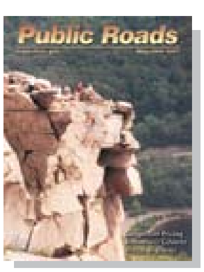

Front cover—The iconic rock formation of New Hampshire's Old Man of the Mountain in Franconia Notch, shown here, is featured on State highway signs. The rock profile, which was damaged during a rock slide in 2003, overlooks I-93. The New Hampshire Department of Transportation convened a citizen panel to set direction for the State's transportation plan, described in the article, "A Call to Action," on page 20. *Photo by Dick Hamilton, Photographer.*

Back cover—Pedaling a tandem bicycle, Jack and Pat Deacon are enjoying their ride on a two-lane road in Kentucky, State Route 11, in October 2005 during the annual Red River Bicycle Rally, which is sponsored by the Bluegrass Cycling Club. The light traffic on the rural road helped make the ride a memorable experience for participants in the rally. *Photo by Karen Shawhan.*

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Guest Editorial

Excellence in Transportation Design Through Context Sensitive Solutions

The highway planners, designers, and builders of today have learned that success means a marriage between traditional engineering and safety considerations. Also essential to success is improved collaboration with citizens, organizations, and agencies, focused on minimizing the impacts of highways on the environment and communities. The Federal Highway Administration (FHWA) is committed to these goals through the endorsement and support of context sensitive solutions (CSS) and has formally adopted CSS as one of the Agency's vital objectives of environmental stewardship and streamlining.

CSS is a collaborative, interdisciplinary approach that involves all stakeholders to develop a transportation facility that fits its physical setting and preserves scenic, aesthetic, historic, and environmental resources, while maintaining safety and mobility. The CSS approach considers the total context for a transportation improvement project and normally includes the early, continuous, and meaningful involvement of the public and all stakeholders throughout the project development process.

In addition, CSS offers many important benefits when integrated throughout the transportation community, such as broadening the definition of the problem that a project is intended to solve; reaching consensus with all stakeholders before the design process begins; conserving environmental, monetary, and community resources; streamlining the National Environmental Policy Act process; shortening the project development process through early consensus, thereby minimizing litigation and redesign; and expediting permit approvals. CSS also builds public and regulatory support. By partnering and planning a project with the transportation agency, these stakeholders bring full cooperation and often additional resources as well.

Today, the focus of many States has shifted from expanding the highway system to managing congestion and improving existing facilities, most of which are located in built-out areas and communities. Stakeholders expect that transportation improvement projects not only fit into this built environment but also offer enhancements. Working with community stakeholders to preserve and enhance the human and natural environment thus becomes a significant challenge and opportunity.

The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) places strong emphasis on advancing CSS in everyday transportation decisionmaking. In SAFETEA-LU section 6008, the standards laid out in section 109(c)(2) of title 23 of the United States Code were amended to include eight "characteristics of the process that yield excellence" and seven "qualities that characterize excellence in transportation design."

FHWA is encouraging the integration of CSS throughout Agency decisionmaking, and the performance objectives will include measures of success based on a national assessment and validation of CSS progress in each State.

FHWA is committed to working with partners and stakeholders to make CSS a reality in all transportation decisionmaking across the Nation. States may take full advantage of the technical expertise and experience that FHWA has to offer. As a part of the future, CSS serves the public interest, helps build and strengthen communities, and, ultimately, leaves a better place behind.

Gloria M. Shepherd

Gloria M. Shepherd
Associate Administrator
FHWA Office of Planning, Environment, & Realty

High-Performance Highways

by Patrick DeCorla-Souza

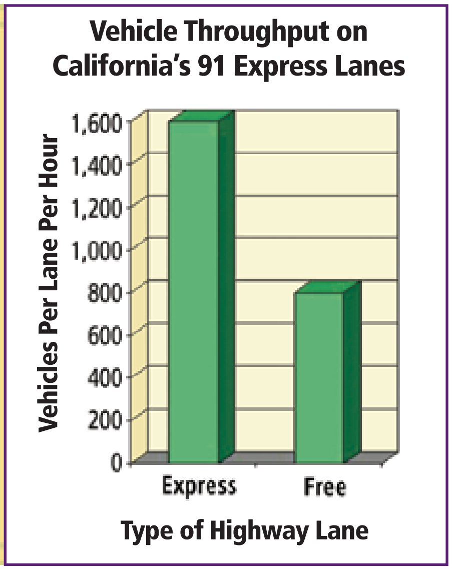
Pricing may be one solution to managing congestion on the transportation network, with implications for financing tomorrow's infrastructure.

(Above) As growing traffic volumes continue to hamper mobility on U.S. roadways, such as on this Texas highway, transportation officials are looking for new strategies to ease the congestion. Using variable tolls is one approach under consideration. *Photo: Texas Transportation Institute.*

Growing congestion on the transportation network poses a substantial challenge for the U.S. economy and for the quality of life of millions of Americans. Highway congestion in metropolitan areas has increased dramatically over the past two decades. According to the Texas Transportation Institute's *The 2005 Urban Mobility Report*, U.S. motorists spent 0.7 billion hours sitting in traffic in 1982; the number had jumped to 3.7 billion hours by 2003. During that period, the costs associated with congestion skyrocketed from $12.5 billion (in 2003 dollars) to $63.1 billion. Further, according to 2003 data, congestion wastes nearly 2.3 billion gallons of fuel, as motorists and truckers sit idling on congested roadways.

Congestion pricing—sometimes called value pricing—is one tool that may help relieve congestion in the short term and reduce the wastes associated with idling traffic. Congestion pricing charges motorists to use highways during peak periods. As a result, it encourages motorists to shift some rush hour travel to other transportation modes or to offpeak periods. Although commercial vehicles have less discretion to travel at different times of the day, the benefits from congestion pricing in terms of the delay and fuel cost savings far outweigh the extra monetary costs incurred for congestion charges.

The 1,600 vehicles per hour per lane permitted on California's 91 Express Lanes is an average for a 2-month period in 2004. Because the tolls are prescheduled every 3 months, toll rates cannot be changed on a day-to-day basis to respond to unusual demand spurts on any particular day. Therefore, there must be a "cushion" to ensure that the threshold value for flow breakdown is not exceeded on any day due to unusual demand.



Source: Based on data provided by Orange County Transportation Authority in April 2004.

By removing at least some of the noncommuting drivers from congested roadways during the rush hours, congestion pricing enables traffic to flow more efficiently. For example, daily traffic data for vehicles inbound in the morning on I–66 outside the Capital Beltway in the Washington, DC, metropolitan area show that vehicle flow drops from about 8,000 vehicles in the 1-hour period from 6 a.m. to 7 a.m. to less than 6,000 vehicles in the hour from 8 a.m. to 9 a.m.

Of particular interest to congestion experts at the Federal Highway Administration (FHWA) is a concept known as high-performance highways, which involves applying variable tolls on *all* lanes of existing tollways and toll-free facilities to manage traffic flow. Tolls would vary by level of demand, either on a fixed schedule by time of day (such as in half-hour blocks) or in real time (such as every few minutes, if necessary) and would be charged *only on congested highway segments* to manage traffic flow. Previously, the chief method for high-performance freeway operations was through ramp management. To provide travel alternatives, the high-performance highway concept also would involve promoting carpools and vanpools, offering park-and-ride facilities, and providing fast, frequent, and inexpensive express bus service on the tolled roadways. All vehicles, except authorized buses, would be charged a variable toll set high enough to guarantee that high demand will not cause traffic flow to break down.

Numerous economic, financial, operational, political, social, and technological considerations constrain how highway managers can price road use. And, ultimately, each State or locality will need to choose the pricing configurations deemed optimal to deal with these many considerations. "The high-performance highway is not the only, nor necessarily the best, approach to pricing roadways," says Regina McElroy, director of the Office of Transportation Management at FHWA. "However, it attempts to deal with multiple considerations on a comprehensive basis, illustrating ways to accommodate high levels of system performance and economic efficiency within a broad framework of public acceptance and political reality."

The High-Performance Concept

The high-performance highway approach is rooted in the fact that when traffic volume exceeds a certain threshold level, both vehicle speed and throughput drop precipitously. Data from the Washington State Department of Transportation's 2006 report *Measuring Delay and Congestion: Annual Update* show that maximum vehicle throughput on freeways in the State of Washington occurs at speeds of about 67 kilometers per hour, km/h (42 miles per hour, mi/h) to 82 km/h (51 mi/h).

"The number of vehicles that get through per hour frequently drops by as much as 35 percent when severe congestion sets in and speeds drop to crawl speeds of 20 to 30 mi/h [32 to 48 km/h]," says Pravin Varaiya, an expert in transportation operations research, optimization, and performance management. "Traffic flow is kept in this

Orange County Transportation Authority

Eastbound traffic is shown here on the 91 Express Lanes in Orange County, CA. Motorists in the toll lanes (center) are experiencing more efficient travel, while the free lanes (right) are congested with traffic.

San Diego Association of Governments

Highway operators can use variable message signs like this one on the I–15 Express Lanes in California to adjust and display toll charges as they vary throughout the day.

condition of collapse for several hours after the rush of commuters has stopped. This causes further unnecessary delay for offpeak motorists who travel after rush hours."

According to the high-performance highway concept, transportation operators charge variable tolls on tunnels, bridges, and existing toll roads and toll-free highways on *all* lanes but *only* on critical congested segments, not on the entire system. The variable toll dissuades some motorists from using limited-access highways (generally freeways) at critical bottleneck locations where traffic demand is high and where surges in demand could push the freeway over the threshold at which traffic flow collapses. Applying pricing to entire segments of roadways during congested periods in effect turns all lanes into premium service lanes. Not only are *more* motorists able to reach their destinations during the rush hours, but also they get there *faster.*

In Orange County, CA, for example, toll lanes built in the median of State Route 91 (S.R. 91) carry a much higher volume of vehicles per lane than the adjacent general purpose lanes during the hours with heaviest traffic on the eastbound direction. "With the use of congestion management pricing, travel on the 91 Express Lanes during peak period hours captures 40 percent of the traffic volumes with only 33 percent of the capacity," says Kirk Avila, general manager of the 91 Express Lanes for the Orange County Transportation Authority. Based on the success of tolling efforts such as the 91 Express Lanes, FHWA officials extrapolate that if all lanes were tolled, then the throughput would be greater across the entire network.

Implementing the Concept

On a high-performance highway, peak period commuters would have several traveling options:

- Pay a relatively low toll for the convenience of driving alone in free-flowing traffic on the high-performance highway.
- Join a carpool or vanpool and enjoy a fast trip on the high-performance highway for an even lower price by sharing the cost of the toll. (Free or discounted service for carpools or vanpools could be a policy option but would increase enforcement challenges.)
- Use newly expanded and more convenient services provided by express buses that run on the high-performance highway.
- Drive alone for free on the arterial street system.

Congestion pricing strategies involve "open road" tolling, which means collecting fares without using traditional stop-and-pay toll booths. All tolls are collected electronically at highway speeds, and transportation operators can choose from a variety of mechanisms to collect the tolls. Licensed drivers in the area covered by the priced network could be issued inexpensive electronic transponders (such as a sticker tag, which is a thin decal that is similar to a conventional battery-operated tag but requires less maintenance) free of charge, along with a transportation account. As with telephone service, the account holder receives a monthly bill. The bill may be paid automatically if the account is linked to a credit card provided by the account holder. Nonresidents could purchase the tags at retail outlets, such as convenience stores or gas stations, or from automated teller machines at welcome centers located at approaches to metropolitan areas.

Motorists without transponders could be video-tolled, meaning that cameras would take pictures of their license plates, and the vehicle owners would be charged for the toll plus a small administrative fee to cover the extra costs. On November 1, 2006, Florida's Turnpike Enterprise, in conjunction with the Tampa-Hillsborough Expressway Authority, launched a pay-by-plate system, the first video-toll account system in the United States. Customers who are occasional users of the Lee Roy Selmon Crosstown Expressway (between Tampa and Brandon, FL) and do not have a transponder can call a toll-free number to open an account.

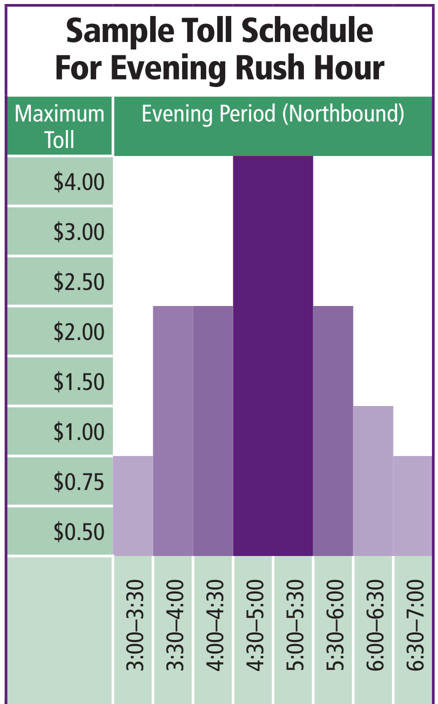
"They pay a toll of $1.25," says Jim Ely, executive director of the Florida Turnpike Enterprise, "instead of the $1.00 paid by those with transponders, which is only a small premium charge in order to cover costs to process the license plate images."

To provide predictability of costs for motorists, highway managers could set the toll rates to vary by time of day on a fixed schedule. The schedule could be adjusted periodically, if necessary, to address changing demand. The operators of California's 91 Express Lanes adjust the toll rates on a quarterly basis.

To ensure that day-to-day variations in highway demand do not cause breakdowns in traffic flow, highway managers may need to manage freeway use in real time. Airlines offer free flight tickets or cash to induce some ticket holders to give up their seats when flights are overbooked. Highway managers can apply this concept to the freeway system by creating *optional-use* lanes with ramp meters at entrance ramps. If sufficient pavement does not already exist at the ramps, some minor pavement widening might be needed. As motorists approach an entrance ramp, they would choose between two lanes. Those who are in a hurry or choose to pay the posted toll simply enter the mainline traffic. Those who have more flexibility in their schedule could opt to wait in an optional-use lane. Traffic signals would control entry of traffic into the mainline freeway from the optional-use lanes. Those who choose to wait in those lanes would be compensated for their delays by credits to their transportation accounts. Highway managers could post the amount of credit offered and estimated delay times on variable message signs at the entrance ramps, so motorists arriving at the ramps could decide for themselves whether the compensation offered would be acceptable to them or whether they prefer to enter the freeway without delay.

The Transit Advantage

Another key component of the high-performance highway concept is the provision of travel alternatives, such as park-and-ride facilities and vanpool and transit services. It is important that premium transit services be available a few months *before* pricing becomes operational. Where free-flowing high-occupancy vehicle (HOV) lanes do not exist on the congested network, agencies could build or designate highway shoulders as bus lanes for use by transit and authorized vanpools and paratransit vehicles during congested periods. The lanes could operate in each direction on all freeways, in conjunction with the introduction of new transit and vanpool services, and could be discontinued after all freeway lanes are restored to free flow with pricing. Ensuring travel time advantages relative to driving alone is critical to the success of new transit and vanpool services.



This table shows an example of a variable toll schedule, this one for maximum rates that are charged on the I–15 Express Lanes in San Diego, CA. *Source: San Diego Association of Governments.*

The Minnesota Department of Transportation (Mn/DOT) has a 14-year history of designating bus shoulders on highways in the Minneapolis-St. Paul metropolitan area. Mn/DOT requires that the pavements for bus shoulders be at least 18 centimeters (7 inches) thick and at least 3 meters (10 feet) wide. "Where pavements are strong enough and wide enough, highway agencies could designate a bus shoulder using signage," says Jennifer Conover, the Team Transit project manager who oversees Mn/DOT's bus shoulder program. "Buses using the shoulder operate at slow speeds—35 mi/h [56 km/h] or 15 mi/h [24 km/h] faster than the adjacent congested traffic. Restricting use of the bus shoulders to authorized vehicles with trained drivers traveling at slow speeds ensures that safety is not compromised while creating a transit advantage."

Benefits of High-Performance Highways

Because all lanes are priced, high-performance highways avoid the need for additional rights-of-way and pavement to construct barriers or buffer separations between priced lanes and toll-free, general purpose lanes. All lanes therefore become premium service lanes, accessible from existing interchanges and available for use by all vehicles. Without barriers separating the lanes, high-performance highways avoid the need for traffic to merge into and out of priced lanes from adjacent general purpose lanes. Such weaving movements are inconvenient for buses and motorists and reduce safety and highway capacity.

Further, because motorists are free to switch lanes, high-performance highways help maximize capacity. A slower moving vehicle in a separated single lane causes a gap to build up in front of it, reducing vehicle throughput per hour. In addition, when fewer adjacent lanes are available for use by all traffic, vehicle throughput per lane per hour is reduced, because faster drivers find it more difficult

Traveling on an authorized bus shoulder, this bus is bypassing congested traffic on I–35 outside downtown Minneapolis.

Dave Gonzalez, Mn/DOT

to switch lanes and overtake slower vehicles to occupy large gaps between vehicles.

Because new rights-of-way and expansion of highway infrastructure are not prerequisites for implementation, agencies could put an entire high-performance highway network in place in a metropolitan area in a relatively short time. The time-consuming environmental review processes generally associated with highway widening projects would be unnecessary and therefore would not delay implementation. Some new investment would be necessary for managing and operating the highway and arterial networks, initiating new express bus and vanpool services, and building new park-and-ride facilities. Those steps, however, would not require the extent of environmental review normally necessary for widening projects.

With high-performance highways, much more premium service capacity is available on multiple lanes. Therefore, relatively lower toll rates are sufficient to ensure that traffic volumes do not rise above available capacity, making the use of high-performance highways more affordable to a larger population of middle- and lower-income motorists.

Most important, with a high-performance highway, all lanes should remain congestion-free.

Addressing Public Acceptance

The notion of introducing high-performance highways may raise concerns among the driving public. Perhaps chief among them is that the scheme will not work, and motorists will pay more just to sit in the same traffic jams. To alleviate concerns about whether this approach would actually reduce congestion and benefit motorists, transportation officials could propose the pricing scheme as a short-term experiment, with permanent implementation subject to citizen approval by referendum. Stockholm, Sweden, offers an example, where a highly publicized trial run of congestion pricing lasted for 7 months from January through July 2006, with a public referendum on its continuation held that September. The measure passed with 53.1 percent voting in favor and 45.5 percent against.

Mn/DOT uses signs like this one to denote authorized bus shoulders along stretches of freeway and arterial highways between Minneapolis and St. Paul.
Photo: Jennifer Conover, Mn/DOT.

To further alleviate doubts about the effectiveness of high-performance highways, the transportation operator could offer a money-back guarantee to toll-paying motorists who do not receive the promised levels of service (that is, travel speeds). If a crash or road construction slows travel, the delayed motorists would not be charged, or charges would be reduced to reflect the reduced level of service.

Another concern is the argument that the public already paid for the highways through taxes, so new tolls would amount to double taxation. One means to address this issue is to invite motorists to share in the net proceeds from the pricing scheme. Net toll revenues (after paying for maintenance and operation of the high-performance system) could be returned to motorists on a monthly basis in the form of credits to their transportation accounts.

Each motorist's share of the net revenue could be determined based on net revenue divided by the number of eligible motorists in the area. Registered drivers who have transportation accounts but rarely use heavily traveled roads—perhaps they take public transit or carpool—would be rewarded, while those who choose to use scarce and valuable highway capacity would have to pay more. This would change the current system used to pay for roads from something akin to an "all-you-can-eat" buffet system, under which everyone pays a fixed charge and can consume as much as he or she likes, to an a la carte system, where people make efficient consumption choices based on the price they are willing or can afford to pay. The credits could be used to pay for tolls, transit fares, or parking charges at park-and-ride facilities.

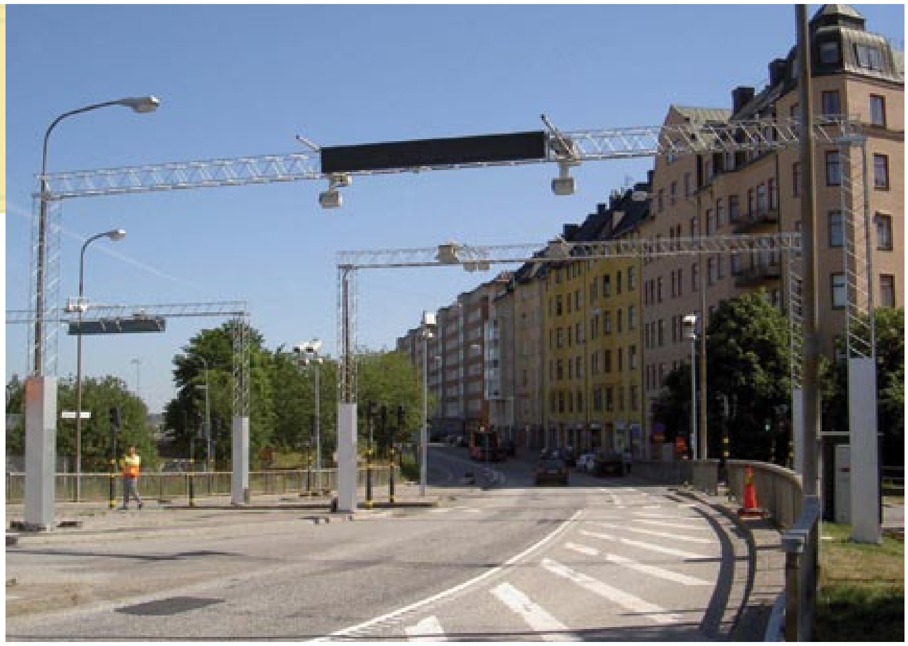
Transportation agencies could issue credits on a rotating basis over the course of each month, thereby avoiding situations in which too many motorists attempt to use their free credits for tolls on the same day, thus swamping the network with extra traffic. At the motorist's option, unused credits could be redeemed at the end of the year toward payments for annual vehicle registration fees and taxes.

As an alternative to dispensing credits on a monthly basis, highway managers might opt to distribute net toll revenues annually to owners of registered vehicles in the metropolitan area, through rebates on vehicle taxes and registration fees generally charged annually.

In cases where toll rates are high enough to produce revenues that exceed the cost of providing additional transportation capacity, additional capacity may be necessary. In such cases, highway managers could use the surplus revenue to build new capacity so motorists who pay the high charges can see that their tolls are being used to address mobility issues.

A third possible concern regarding high-performance highways is the idea that low-income motorists, who have less flexibility in their work hours than many white-collar,

This gantry is located at a cordon charging point at the boundary of Stockholm's city center. Tolls that varied by time of day were charged here on a fixed schedule. *Photo: IBM.*



higher income workers have, will be unable to afford new congestion tolls. Some might argue that it is unfair for the government to provide improved mobility only for the wealthy. However, the high-performance highway concept includes travel alternatives in the form of park-and-ride facilities and express buses, vanpools, and carpools. These alternatives provide an efficient and more cost-effective means of travel during rush hour for low-income commuters and others who may not have the flexibility to travel at less congested times or who simply do not want to pay the full cost of tolls.

For the high-performance highway to be successful, travel alternatives such as vanpools and new express bus systems must be in place *before* introducing congestion tolls, and routes and schedules must be beneficial to customers. Highway managers should offer fare-free transit promotions and vanpool trial periods to encourage use of these new services. These promotions would enable the public to become familiar with the new modal options and minimize public concerns about the viability of travel alternatives.

In addition, low-income commuters could receive discounts on tolls, transit fares, or parking charges at park-and-ride lots. Drivers could access the parking lots by using smart cards linked to their transportation accounts.

Finally, the public may be concerned that adjacent free roads will become more congested because motorists will divert from priced highways to the free routes to avoid the new congestion tolls. Experience has shown that when highway managers raise toll rates on existing tollways, some drivers divert to toll-free arterials or surface streets to avoid paying the higher rates. However, unlike conventional tollways, priced highways provide more travel options.

Several key differences reduce the likelihood of traffic diversion on parallel toll-free facilities:

First, variable tolls with a stepped rate schedule provide options for motorists to reduce or eliminate their costs for new tolls by shifting their time of travel. In the case of tollways with flat tolls all day, drivers cannot escape tolls or avail themselves of a lower toll rate simply by traveling at a different time.

Second, the introduction of variable tolls during congested periods would be accompanied by an expansion of transit capacity and the availability of carpool and vanpool options, so some solo drivers may shift to using transit or carpools rather than diverting to parallel toll-free roadways.

Third, when agencies introduce pricing on highways that used to be severely congested, some motorists who previously switched to parallel arterials may shift back to the free-flowing priced highways. And faster moving traffic on priced highways could result in an increase in vehicle throughput per hour, thus accommodating higher rush hour traffic volumes.

As long as parallel arterials remain toll-free, however, motorists who divert from the priced highways or shift from other less convenient times of travel may take the place of any traffic that shifts from the arterials to the priced highways. Thus, although total vehicle throughput per hour in the corridor may increase, arterial congestion is unlikely to improve during key congested periods. However, the duration of congestion (that is, the length of the congested period) may decrease.

On the other hand, highway managers could use toll revenues to pay for optimizing traffic signal controls on parallel arterials wherever they are not currently optimized. This approach could help improve traffic flow on the arterials.

Gaining Public Acceptance for a Broad Pricing Approach

- Propose the pricing scheme as a trial or pilot project subject to referendum
- Provide a money-back guarantee for premium service
- Return surplus revenue to motorists, or use revenues to provide direct benefits, such as additional lane capacity, to motorists who pay the tolls
- Provide travel alternatives, such as express bus services and park-and-ride facilities
- Provide toll discounts for low-income motorists
- Improve arterials with signal optimization

Costs, Benefits, and Revenues

Researchers at FHWA recently used a modeling program called the

Tool for Rush Hour User Charge Evaluation (TRUCE) to estimate the potential costs, benefits, and revenues of operating a high-performance highway. The planning tool is available on FHWA's Web site at www.ops.fhwa.dot.gov/tolling_pricing/value_pricing/tools/index.htm.

The researchers assessed three scenarios representing typical congestion levels on highway networks in major U.S metropolitan areas. They based the scenarios on a prototypical area (either a metropolitan area or a significant portion of a major metropolitan area) with approximately one million drivers and an existing 161-kilometer (100-mile) highway network comprising a total of 966 lane kilometers (600 lane miles). The study highways averaged six lanes (three lanes in each direction). The congestion-level scenarios were as follows:

A moderately congested freeway network, as defined in the study, would have average peak period speeds of 69 km/h (43 mi/h) and a total of 4 hours of congestion per day, that is, about 2 hours in the morning and 2 hours in the evening. The average speed represents a composite of higher traffic speeds on some segments of the network and much slower congested speeds on other segments. Assuming a free-flow freeway speed of 97 km/h (60 mi/h), this scenario represents a peak period travel time index (that is, ratio of average peak period travel time to free-flow travel time) of 1.4. Portland, OR, is a typical example of a metropolitan area with these characteristics.

A severely congested freeway network, would have average peak period speeds of 64 km/h (40 mi/h) and a total of 5.5 hours of congestion per day, or about 2.5 hours in the morning and 3 hours in the evening. This scenario represents a peak period travel time index of 1.5. The Washington, DC, metropolitan area is an example of a severely congested network.

An extremely congested freeway network, would feature average peak period speeds of 55 km/h (34 mi/h) and a total of 7 hours of congestion per day, or about 3 hours in the morning and 4 hours in the evening. This scenario represents a peak period travel time index of 1.75. Portions of highways in the Los Angeles, CA, metropolitan area qualify as extremely congested networks.

Using the TRUCE software, the FHWA researchers estimated the toll revenues, benefits, and costs associated with a multimodal pricing package that includes transit and park-and-ride services. They determined that benefit/cost ratios would range from 1.4 to 2.8, depending on the severity of existing levels of congestion, indicating that a multimodal pricing package would be economically efficient. "Because the TRUCE model uses conservative assumptions to project benefits, these estimates are on the low end," says Jack Wells, chief economist at the U.S. Department of Transportation (USDOT). "The model does not account for environmental and safety benefits, benefits to businesses and the economy, and increases in energy security."

Surplus revenue would be higher in more severely congested areas because of higher toll rates and longer congested periods during which tolls would be charged. Based on FHWA calculations, annual toll revenue surpluses could range from $40 million to $226 million. This surplus could provide an annual tax refund to area motorists of $40 to $226 per driver, or credits to their transportation accounts of $3 to $18 per month.

Congestion Pricing: Estimated Benefits, Costs, and Revenues

	Initial Congestion Level		
Annual Benefits (Million $)	**Moderate**	**Severe**	**Extreme**
Highway Benefits	$105.80	$184.51	$360.49
Transit Benefits	$5.18	$9.02	$17.55
Multimodal Benefits	$110.99	$193.53	$378.04
Annual Costs to Transportation Network (Million $)			
Highway Costs	$25.46	$33.34	$41.21
Transit Costs	$52.50	$72.19	$91.88
Multimodal Costs	$77.96	$105.53	$133.09
Multimodal Benefit/ Cost Ratio	**1.4**	**1.8**	**2.8**
Annual Toll Revenues Versus Costs (Million $)			
Toll Revenues	$118.19	$196.35	$358.85
Multimodal Costs	$77.96	$105.53	$133.09
Surplus	**$40.22**	**$90.82**	**$225.76**

Source: FHWA.

Urban Partnerships

High-performance highway networks represent one approach to curbing the growing burden of traffic congestion. Converting *all* lanes on existing freeways into premium service, variably tolled, free-flowing highways *during peak periods only*, coupled with fast, frequent, and inexpensive express bus service, could provide social benefits that far exceed multimodal investments and operating costs. When implemented in large metropolitan areas or portions thereof, possibly by public-private partnerships, these networks could generate toll revenues that would be sufficient to cover all management and operational costs, including the funding necessary to introduce new express bus and park-and-ride services.

The nation-city of Singapore is the only entity known to have implemented the high-performance highway concept on a network-wide basis. Singapore introduced peak period pricing in the downtown area during the morning rush hours in 1975. In spring 1998, the city shifted to a fully automated electronic charging system, with in-vehicle electronic devices allowing payment by smart card, and enforcement using cameras and license plate reading equipment. Singapore also introduced variable electronic charges on the expressway system, with charges set by time of day to ensure the free flow of traffic. The system is the first of its kind in the world and has reduced congestion in that city significantly. During the peak periods, more than 95 percent of expressways and major arterial roads are smooth-flowing and congestion-free, according to Singapore's Land Transport Authority.

In May 2006, USDOT announced its National Strategy to Reduce Congestion on America's Transportation Network (the Congestion Initiative), a comprehensive national program to reduce congestion on the Nation's roads, rails, runways, and waterways. One major component of the initiative is the Urban Partnership Agreement. USDOT is soliciting proposals by metropolitan areas to enter into partnership agreements with USDOT to demonstrate strategies with a track record of effectiveness in reducing traffic congestion. To support broader adoption of successful strategies, USDOT officials expect to use discretionary funding available under the Department's Intelligent Transportation Systems Operational Testing to Mitigate Congestion Program, its Value Pricing Pilot (VPP) program, and other grants. In addition, to the extent possible, USDOT will support its urban partners with regulatory flexibility and dedicated expertise and personnel.

Land Transport Authority, Singapore

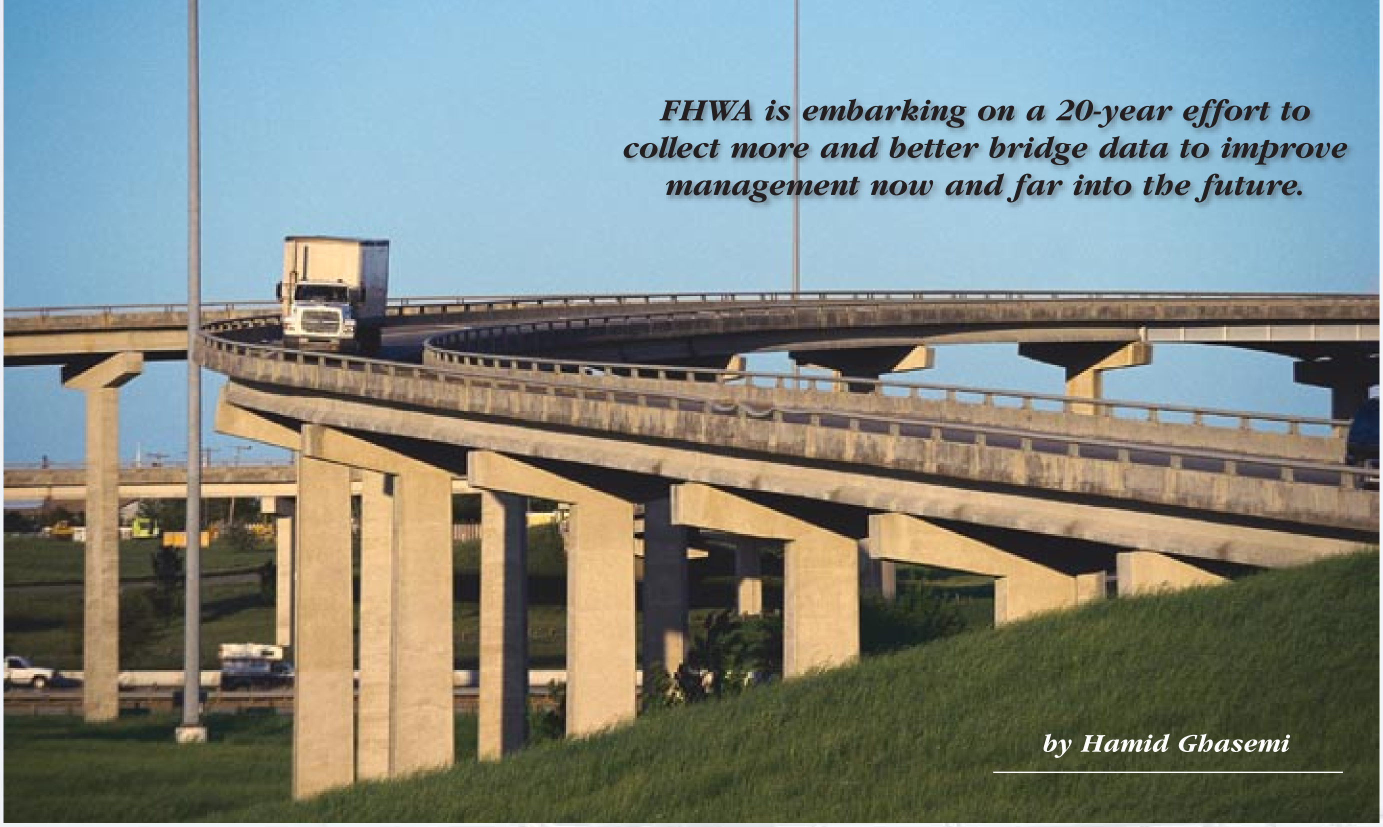
This photo shows a gantry on a variably tolled expressway in Singapore. Toll rates vary by time of day and are adjusted periodically to ensure free flow of traffic while maximizing vehicle throughput.

FHWA is actively encouraging States and metropolitan areas to apply for grants under the urban partnership program to test and demonstrate congestion pricing concepts such as the high-performance highway. Metropolitan areas with severe congestion may submit applications for consideration for funding.

Patrick DeCorla-Souza, AICP, is program manager for urban partnerships at FHWA in Washington, DC. He has provided direction to FHWA's VPP program since 1999 and works with public and private sector partners nationwide to implement innovative road pricing strategies. DeCorla-Souza cochairs the Transportation Research Board's Congestion Pricing Committee and has master's degrees in transportation planning and civil engineering.

For more information on Urban Partnership Agreements, please visit www.fightgridlocknow.gov or contact Thomas McNamara at 202-366-4462, thomas .mcnamara@dot.gov or Patrick DeCorla-Souza at 202-366-4076, patrick.decorla-souza@dot.gov.

This article is the fifth in a PUBLIC ROADS series on innovative financing. One of FHWA's priorities is encouraging the use of innovative financing.



FHWA is embarking on a 20-year effort to collect more and better bridge data to improve management now and far into the future.

by Hamid Ghasemi

Bridging the Data Gaps

According to the National Bridge Inventory (NBI) database, nearly 600,000 highway bridges stitch together the Nation's highway network, making the system dependent on their integrity if it is to continue to provide seamless transportation to the traveling public. Skillfully managing these various structures is vital to the movement of goods and people around the United States.

Given the wide range of bridge structure types, material characteristics, age, daily traffic, and climatic conditions, management requires knowledge in many areas, including performance characteristics, deterioration models, and quantitative data. "The magnitude of capital investment in bridges and their impact on safety, mobility, and national security clearly require a proactive approach in management of the U.S. bridge inventory," says Tom Everett, principal bridge engineer for the Federal Highway Administration (FHWA).

(Above) This truck is exiting a freeway ramp typical of those to be monitored.

Many initiatives for improving bridge management have been undertaken, especially since the infamous collapse of the Silver Bridge at Point Pleasant, WV, in 1967. The latest initiative is FHWA's Long-Term Bridge Performance (LTBP) program, which was authorized in 2005 under the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). The program is strategic and ambitious, a 20-year research effort that has both long-range and short-term goals. It will be similar to the Long-Term Pavement Performance (LTPP) program that began in 1987 through the Strategic Highway Research Program. The framework of LTPP offers components that could prove useful in the new LTBP program.

To initiate the bridge program, FHWA is developing specifics regarding program goals and criteria, and is publicizing them throughout the United States. FHWA drafted a framework with help from the Center for Innovative Bridge Engineering at the University of Delaware. Stakeholders in the public, private, and academic segments of the highway bridge community, including international interests, are discussing the framework before final approval. Through a series of workshops, FHWA will seek views on all aspects of bridge performance data collection and analysis, long-term monitoring, bridge selection criteria, sensing technologies, nondestructive evaluation (NDE) tools, and expected outcomes and products.

Latest in a Tradition

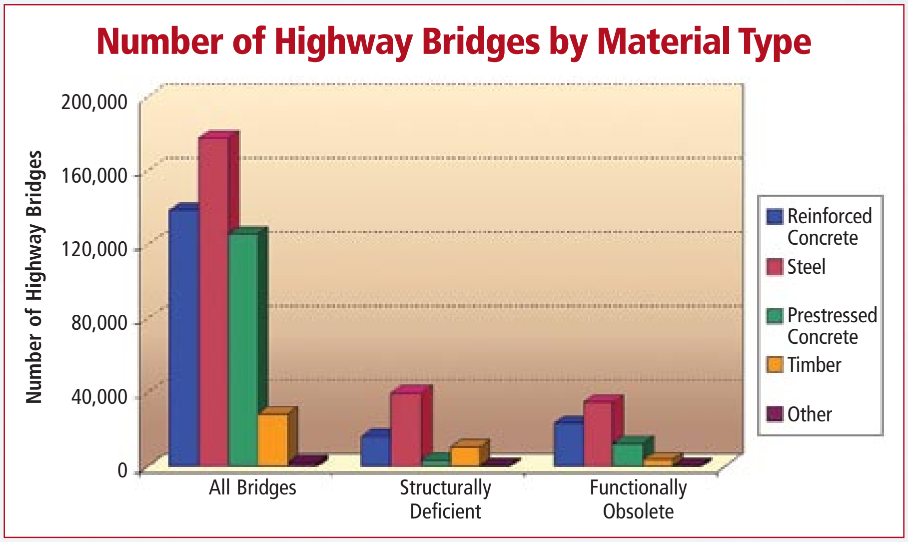
When interstate construction began in the late 1950s, the bridge inventory in the United States already was large, and the bridges were aging. Little consideration was given to assessing bridge conditions at the national level, and there was no uniformity to evaluating performance. This situation continued until 1967 and the failure of the Silver Bridge. The collapse, which spilled rush-hour vehicles into the Ohio River and killed 46, resulted in FHWA's establishment of the National Bridge Inspection

Standards (NBIS) and National Bridge Inspection Program (NBIP) in 1970.

NBIS set minimum bridge inspection criteria and prescribed the methods, frequency, and qualifications for performing inspections. The standards required that qualified professionals inspect highway bridges at least once every 2 years and that results be reported annually to FHWA. The agency has maintained this information in its NBI database since the early 1970s. The database currently contains records on some 472,633 bridges and 124,846 culverts with a span greater than 6 meters (20 feet). The mean age of all bridges in NBI is 40 years.

The scope of NBIP reporting has increased over the years, and the database is now a comprehensive source of bridge inventory and conditions. NBIP is adequate for managing a national program aimed at eliminating bridge deficiencies but not for detailed bridge performance measurement or optimizing maintenance programs. This is mostly due to the subjective nature of the data contained in the NBI database and the lack of detailed, element-level (rather than system-based) bridge information.

The NBI database does not include conditions of specific elements such as protective systems and deck joints. Nor does it provide information on local damage or deterioration. Also, the condition and appraisal ratings are qualitative and too general for developing plans and estimates for repairs or rehabilitation work.



Source: FHWA.

Filling the Data Gaps

Many States have responded to these limitations by collecting element-level bridge data. Although element-level inspections provide more detailed and useful information for bridge management, especially at the State and local levels, the data collected are still limited in several respects. Most significantly, the data are based primarily on visual inspection, augmented only with limited mechanical methods such as hammer sounding or prying.

Many types of damage and deterioration must be identified and measured to determine whether a bridge is safe. Many of these factors are visually detectable when they are at an advanced stage of deterioration. Simply looking at a bridge probably will not determine, for example, whether it has been overloaded. Frozen bearings, corrosion, and fatigue damage can exist without visible indications. Voids in prestressing ducts also can remain undetected. Also, inspectors do not typically collect quantitative information on the operational aspects of bridges, such as congestion, crash history, or use by heavily loaded trucks.

"The LTBP program will begin to fill a few of the information gaps that exist in our current program," says FHWA's Everett. "Specifically, the LTBP program will provide quantitative bridge performance data that will improve designs and enhance models utilized by bridge management systems. Effective bridge management tools and efficient designs are essential to maximizing the benefits of our investments."

The quantitative measures of operational performance mentioned by Everett primarily gauge congestion and level of service, and therefore provide the information that is most meaningful to the traveling public. These measures can help to quantify the value of bridges in terms of user costs and benefits. Analysis of life-cycle costs has not been tapped adequately to assist transportation agencies as they manage bridges and make investment decisions. With the recent move to higher performance materials and advanced structural systems, long-term performance and durability are assumed but not yet demonstrated or quantified.

If the Nation's bridge network is to meet increasing traffic and freight demands, future bridge management systems will require improved life-cycle cost and performance models, better understanding of deterioration, and confirmation of the effectiveness of maintenance and repair strategies. These advances will require higher quality quantitative performance data for the development of new models and decisionmaking algorithms. This is where the LTBP program comes in.

"We believe that this is important research for a number of reasons," says Marc Ansley, chief engineer for

This closeup photo shows the spalled concrete and rusted rebar on the pier cap of a stringer bridge.

Sampling of Issues To Be Investigated by the LTBP Program

Damage	Deterioration	Operation	Service
Impact	Corrosion	Traffic counts	Congestion
Overload	Fatigue	Truck weight	Crashes
Scour	Water absorption	Maximum stress	Reduced traffic capacity
Seismic	Loss of prestressing force	Stress cycles	Delay
Microcracking	Unintended structural behavior	Deflection	Unreliable travel time
Settlement	Chemical changes (e.g., ASR, DEF)	Displacement	Reduced load capacity
Movement	Environmental and climatic stresses	Detours	
Lack of movement		Reduction in speed	

the Structures Research Center at the Florida Department of Transportation. "Current knowledge of how different characteristics affect the durability of bridges is very limited. Also, there are limited data on the long-term behavior of post-tensioned bridges considering time effects—creep and shrinkage—in combination with thermal variations." Finally, Ansley says, "The effectiveness of short-term durability testing to adequately describe the actual performance of a bridge component over a projected 75-year or longer life is unknown."

Objectives

The LTBP program's overall objective is to collect, document, and maintain high-quality quantitative performance data over an extended period of time from a representative sample of bridges nationwide. This performance data will enable bridge owners to address a variety of condition management problems, including assessments of how and why bridges deteriorate; the effectiveness of various maintenance, repair, and rehabilitation strategies, and management practices; and the effectiveness of durability strategies for new bridges, including materials selection. Quantitative data also can be used to improve deterioration models and enhance life-cycle cost analysis; support optimal allocation of resources (in conjunction with decisionmaking tools and algorithms); support performance measures for serviceability and structural safety; assess the operational performance of bridges (focusing on congestion, delay, and crashes); and facilitate the validation and improvement of design provisions.

Program Vision

FHWA's vision for the LTBP program is threefold, with collection of data being the common thread. First, a number of bridges that represent the majority of structure types in the NBI database will be subjected to a long-term (at least 20 years and preferably longer) program of detailed inspection and evaluation. The resulting database will support improved designs, predictive models, and bridge management systems.

Second, a subset of the above bridges will be outfitted with instruments to permit continuous monitoring of operational performance under all conditions.

Third, decommissioned bridges will undergo "autopsies" to help improve the knowledge base and the ability to determine the capacity, reliability, and failure modes of bridges in a variety of conditions. These conditions could include damage due to corrosion, overloads, alkali-silicate reaction, fatigue, and fracture. In all three approaches, the LTBP program will take advantage of state-of-the-art sensing and NDE tools.

Components of the LTBP Program

The LTBP program's framework has two components: program management and technical execution. Management and administration, which will be modeled somewhat after the LTPP program, will involve a prime contractor overseeing the program's day-to-day operations. The contractor will have responsibility for all subcontractors who conduct detailed inspections; annual meetings with stakeholders to review and assess program activities; training for data collection by subcontractors; and outreach and collaborative opportunities to mine data and develop new models, tools, and algorithms. FHWA will form an advisory committee to help guide the program. State responsibilities will include providing access to bridges and bridge files, and supporting safety and traffic control measures. The prime contractor or subcontractors will interact directly with bridge owners and coordinate and conduct bridge inspections.

The technical component of the program concerns the specific data to be collected, bridge sampling, performance measures, technology to support data collection, data quality and collection strategies, and data mining and analysis. Specific data will include damage and deterioration due to overloading, scour, corrosion, deflection, congestion, and myriad other factors. The program also will seek reliable quantitative data on maintenance and rehabilitation activities and life-cycle costs. This data should reflect the type, cost, timing, and effectiveness of upkeep. Cost data should include both direct and indirect user costs.

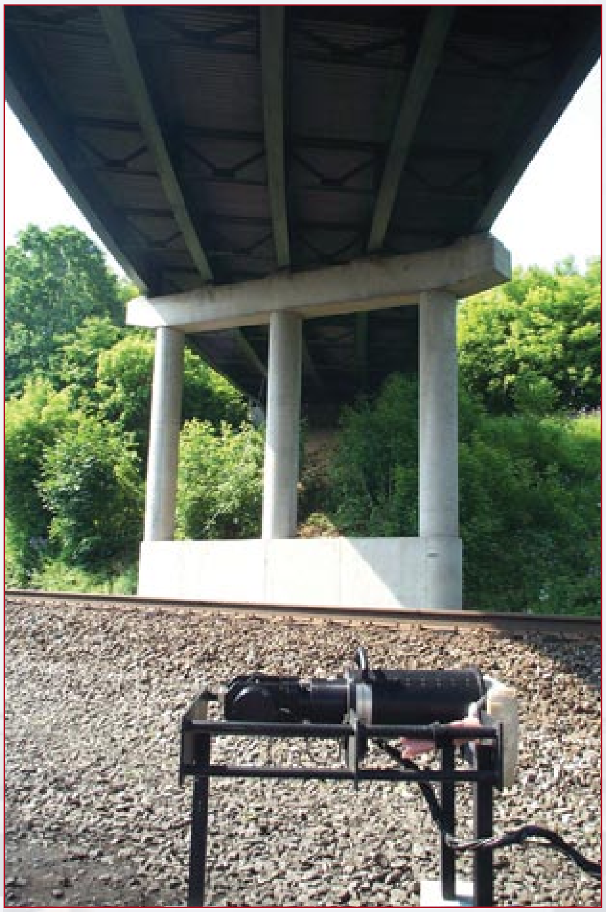
The LTBP program was created as a 20-year research effort, with funding authorized for fiscal year (FY) 2006 through FY 2009. Under current funding, FHWA envisions that most of the LTBP funds will be devoted to detailed periodic inspection, evaluation, and monitoring of bridges. Continuous monitoring and autopsies of decommissioned bridges will be put on hold pending more funding. This will limit information collection to critical data, with clear knowledge of how this data will be used in the future. Data selection should be based on the relationship between bridge performance and deterioration, and on the most important factors that limit bridge performance over the long term. To identify true causal relationships, FHWA will need to include some nonbridge factors, such as load history (for example, truck weights), maintenance activities, geometrics, and so forth. All data should provide a fundamental understanding of bridge behavior, capacity, failure modes, and reasons for performance deficiency.

On data quality and selection strategies, sampling must be used because monitoring and collecting detailed data on the half million bridges in the NBI simply is not feasible. To gain a representative sampling of the Nation's bridges, a study is needed to help guide selection from the NBI database and others such as the Freight Analysis Framework database, which contains quantitative information on average daily traffic and annual truck traffic, tonnage, and traffic volume. The U.S. Department of Transportation created the Freight Analysis Framework as a comprehensive database and policy analysis tool to examine geographic relationships between infrastructure capacity and freight movement for the truck, rail, water, and air modes, and various commodities. Other potentially useful databases include the Highway Performance Monitoring System, Highway Safety Information System, and LTPP system.

Current classifications of bridges are based on the structure types and materials. For the LTBP program, consideration will be given to selecting bridges for study by groups based on performance characteristics that may include physical conditions and traffic and structural capacities. For example, although continuous stringer bridges with integral abutment and simple-span stringer bridges are both slab-on-beam bridges, the former will perform better in terms of durability, reliability, and reserve structural strength.

After classifying bridges and tapping all relevant databases, the final representative sample may be characterized by age distribution, material types (steel, concrete, prestressed concrete, high-performance materials), foundation types, location in different climatic and environmental zones, exposure to different hazards (such as floods, earthquakes, and hurricanes), different annual truck traffic and weights, network of bridges, and different maintenance strategies. Again, the total number of bridges to be inspected and monitored will depend greatly on funding levels, an unknown at this time.

In terms of data collection, NDE and structural health monitoring tools and techniques for testing, monitoring, and evaluating bridges will be crucial to augment visual inspections. FHWA envisions that the LTBP program will help foster technology development and integration. Selected technologies should enable data to be recorded in a format useful to State departments of transportation when they are evaluating maintenance and repair needs.



This laser system in the foreground is measuring the deflection of beams during a load test.

Much of the technology for monitoring bridges is already available as a result of research and development by FHWA and other agencies. In addition, FHWA will develop protocols for data collection, storage, documentation, archiving, access, and dissemination. FHWA will develop and document the protocols to ensure uniformity within the LTBP program and with the hope that they become standards for all future inspection and evaluation programs for infrastructure performance.

Looking Ahead

The immediate short-term needs of the program include the formation of an advisory committee, workshops to seek feedback from the bridge community for formulating future directions and activities of the LTBP program, selection of a lead-support technical contractor to help FHWA in day-to-day operation of the program, and preparation for testing and evaluation of the first set of pilot bridges. This program will generate an extensive and quality bridge database that will help improve the mobility, safety, and reliability of the Nation's bridges.

"FHWA is launching the LTBP program at a critical time," says Bojidar Yanev, executive director for bridge inspection and bridge management at the New York City Department of Transportation. "As a result of the steady improvement in NBI over the last quarter of the 20th century, a second generation of bridge management has become inevitable. Just as computerized data management made NBI possible, the rapidly developing structural monitoring techniques and the growing varieties of construction and maintenance options are making possible the integration of network and project considerations into a new type of adaptable and efficient bridge management system. And just as NBI could only have been established on the Federal level, so is the LTBP program uniquely suited for meeting the new and advanced infrastructure needs."

Hamid Ghasemi manages the LTBP program for FHWA. He joined FHWA's Turner-Fairbank Highway Research Center in 1992 and has been involved in numerous research studies and projects addressing the needs of the bridge community, with emphasis on structural health monitoring, posthazard evaluation, seismic issues, and structural analysis. He was named FHWA's Engineer of the Year for 2000. He received his doctorate in structural engineering from the University of Kentucky.

For updated information on the status of the program, see the LTBP program Web site at www.tfhrc.gov/structur/ltbp.htm. For more information, contact Hamid Ghasemi at 202-493-3042 or hamid.ghasemi@fhwa.dot.gov.

by Kornel Kerenyi and Jorge Pagán-Ortiz

The Maryland State Highway Administration and FHWA partnered to study the effects of scour on these environmentally friendly and economic roadway structures.

Testing Bottomless Culverts

Although hydraulic considerations form the basis of culvert design, the behavior of fish, the characteristics of local soils, and the cost of construction can influence the type of culverts used on highway applications at stream crossings. Bottomless, or three-sided, culverts use the stream's natural channel bed and often are economic and environmentally attractive alternatives to traditional closed culverts.

"We make the selection of culvert type based on all factors involved, taking into account both environmental and engineering issues," says Andrzej Kosicki, assistant chief of the Bridge Design Division, Maryland State Highway Administration (SHA). "Bottomless culverts may be right in some situations, while paved invert culverts may be right in other cases. If we have good soils, especially when the structure foundations can be placed directly on the underlying bedrock without unreasonably high expense, we are more likely to use a bottomless culvert. In order to consider them totally environmentally friendly, we also would look into channel stability questions."

(Above) This bottomless culvert on Whitehall Road over Euclid Creek in Cuyahoga County, OH, is both attractive and environmentally friendly. The culvert spans 12.8 meters (42 feet), rises 3.4 meters (11 feet), and is 12.8 meters (42 feet) long. *Photo: CONTECH.*

Two counties in Maryland—Frederick and Charles Counties—currently are using bottomless culverts on selected stream crossings. These structures typically are supported on spread footings, which have large lateral dimensions that distribute loads to the surrounding soils. Because of the use of spread footings, designers need to address as part of their designs the depth of the footing that will be required to resist to the effects of scour caused by the flowing water. The scour problem is similar to abutment and contraction scour in a bridge opening and can be treated in much the same way.

"In situations where we have to deal with highly erodible, easily scourable soils," says Kosicki, "we are more likely to consider paved bottom culverts unless our studies indicate that foundations can be designed to protect the structure from scour at a reasonable cost."

He adds, "In the mid-1990s, Stan Davis and Dr. Fred Chang, both contractors to Maryland SHA at that time, developed the computer program Abutment Scour (ABSCOUR) to conduct all of our scour studies. But because the equations were derived theoretically from limited experimental data, we wanted to validate them in a lab setting. So about 5 years ago, Stan Davis contacted the Federal Highway Administration's [FHWA] J. Sterling Jones, then the manager of FHWA's Hydraulic Research Laboratory." FHWA and Maryland SHA arranged funding for a cooperative study. Kosicki adds, "FHWA used some excellent equipment to make the scour measurements and to analyze the data obtained."

Design of the Study

Two suppliers, CONTECH® Construction Products, Inc., and CON/SPAN®, agreed to provide models of the configurations that State departments of transportation typically use for highway applications. The primary objective was to compare results from a simple rectangular shape to the results from shapes that are available commercially. For this effort, the FHWA researchers focused on flows assumed to be perpendicular to the roadway.

A major consideration in estimating scour in culverts with open bottoms is the flow distribution at the entrance of the culvert, especially when there is side flow that is being funneled as it passes through the culvert opening.

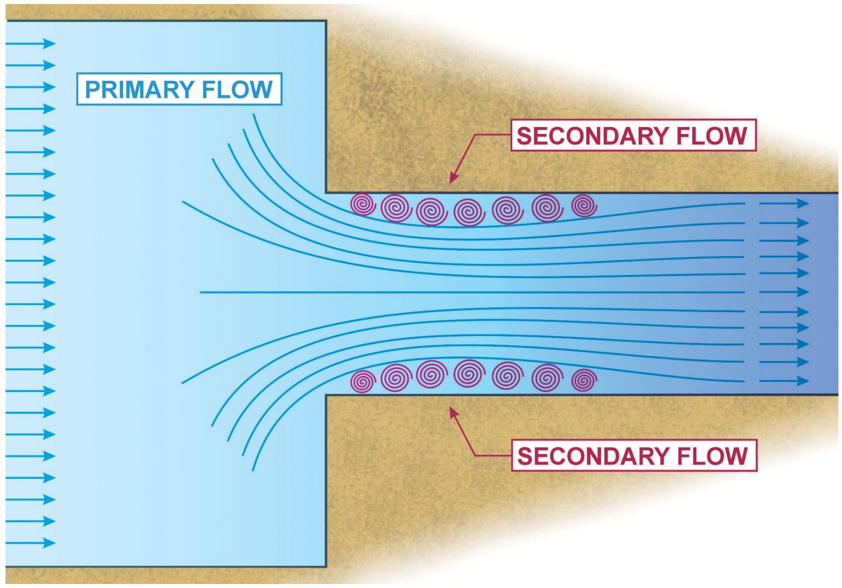
FHWA researchers conducted the study in two phases. The first focused on measuring maximum scour depths at the culvert entrance and developing an analysis procedure using methods described in the *Bottomless Culvert Scour Study: Phase I* (FHWA-RD-02-078) to approximate prescour hydraulic parameters. The researchers conducted submerged entrance or fixed-bed experiments during this first phase to measure prescour hydraulic parameters.

The second phase expanded the investigation to include scour measurements at the entrance and outlets for submerged flow conditions. At the locations where maximum scour occurred, the second phase also involved detailed measurements of velocity with a prescour fixed bed. The researchers conducted additional tests to evaluate the use of various measures to reduce scour, including wing walls (short retaining walls that guide a stream into a culvert), pile dissipators (vertical arrays of circular piles buried just below the channel bed), riprap (rough stones placed to prevent scour), and cross vanes (sets of upstream-angled lines of boulders, connected by a section of smaller rocks upstream).

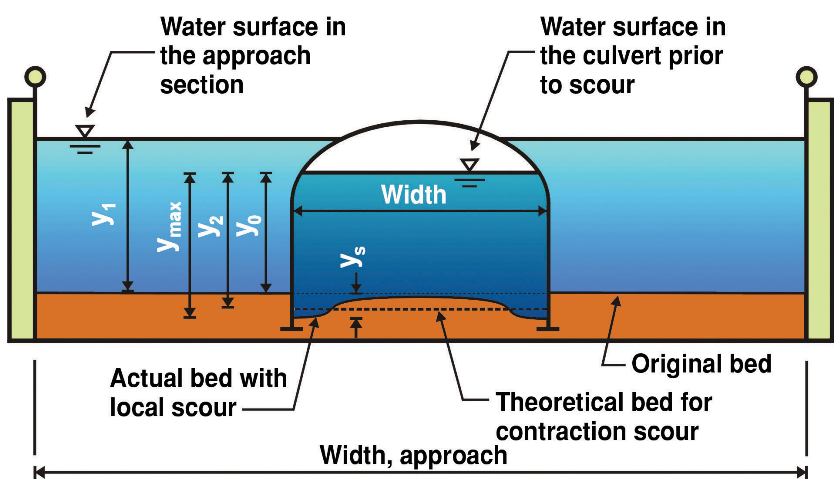
Presentations of status reports on this study to drainage engineers at meetings of the American Association of State Highway and Transportation Officials and at hydraulics conferences revealed a widespread interest in the research, because this type of culvert is considered less intrusive to the environment.

Scour Is a Critical Concern

Experiments show that scour generally is deepest near the corners of the upstream entrance to a culvert because of the contraction or narrowing of the water flow. The vortices and strong turbulence just downstream of the inlet, generated by the contraction of flow typically called secondary flow, occurs in



In this diagram, water flows from the left into a culvert. Embankments constrict the primary flow near the upstream entrance and force the water through the opening. This flow contraction creates a secondary flow of eddies and strong turbulence at the sides of the culvert just downstream of the opening. *Source: FHWA.*



Where:

y_1 = flow depth in the approach channel at a distance of 3 times the culvert width upstream of the culvert

y_0 = water depth at the culvert entrance before scour occurs

y_{max} = maximum water depth in the culvert after scour hole develops

y_2 = equilibrium water depth after scour hole develops

y_s = maximum depth of scour in the culvert

This definition sketch shows a cross section of a flume after a scour experiment for unsubmerged flow conditions. Inside the culvert, measurements show the actual bed with local scour and a theoretical bed for contraction scour. *Source: FHWA.*

Researchers used this Plexiglas® model of a rectangular bottomless culvert for measuring velocity and depth in a controlled environment. The model's upstream entrance is in the foreground, and the bottom of the flume is sand.

the so-called separation zone that is between the side walls of the culvert and the primary flow. This flow pattern is similar to the one observed at bridge abutments that sometimes can lead to large amounts of scour at or near an abutment.

Two reports, *Testing Abutment Scour Model* and the *Bottomless Culvert Scour Study: Phase I,* have suggested that bridge abutment scour can be analyzed as a form of equilibrium scour related to the primary flow by incorporating an empirical adjustment factor to account for vorticity (the swirling motion of a vortex) and turbulence. The earlier research mentioned above established that this empirical adjustment factor could be derived from laboratory results. The FHWA researchers built on this previous work to formulate the theoretical background for analyzing data on culvert scour.

The first variable used in the analysis for unsubmerged flow conditions is the unit discharge, which remains constant as the scour hole develops. If no sediment is being transported into the scour hole, as was the case with all of the experiments in the study, then no sediment could be transported out of the scour hole after equilibrium scour develops. In this case, the local velocity would be reduced to the critical velocity (threshold velocity at which sediment will erode) for the sediment size after the equilibrium scour depth develops. Other variables include the representative (local) velocity at the entrance of the culvert and the critical velocity at which incipient sediment motion occurs.

Also important to note is the assumed representative unit discharge across the scour hole at the beginning of scour. Once the researchers determined the representative velocity and the critical incipient motion velocity, they could derive the equilibrium flow depth that reflects the scour attributed to the incoming flow distribution. The researchers considered three alternative equations for the representative velocity: the average velocity in the culvert inlet, the potential flow velocity (flow theory that is characterized by no curl throughout the velocity field), and the measured flow velocity.

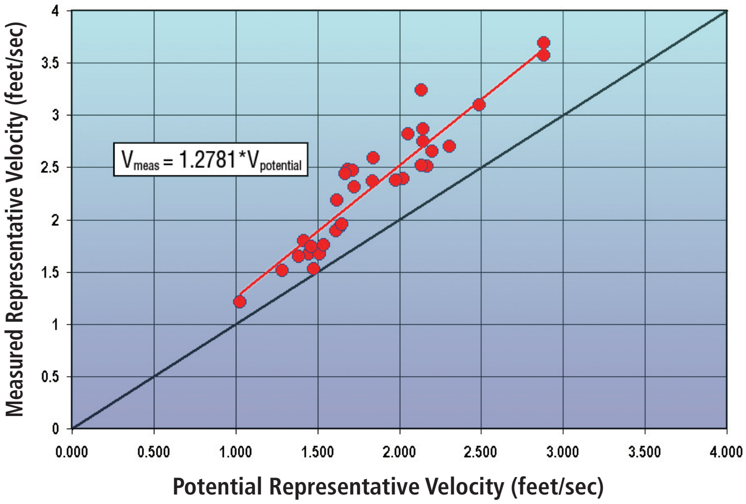
The ABSCOUR program uses the average velocity in the culvert for the representative velocity. This average velocity is the volumetric flow rate divided by the cross-sectional area of flow in the culvert. Chang, in his presentation "Maryland SHA Procedure for Estimating Scour at Bridge Abutments Part 2—Clear Water Scour," published in the 1998 *ASCE Proceedings of the International Water Resources Engineering Conference*, used potential flow principles to derive a velocity adjustment expression to approximate the representative velocity that should be used for computing bridge abutment scour. This adjustment compensates for the flow contraction at the culvert inlet. The FHWA researchers adapted Chang's expression for use in analyzing bottomless culverts. Because the present study produced accurate measurements for the local (representative) velocities in the approach section of the culvert, the researchers adjusted the potential flow theory to match the measured flow velocities at the corners of the culvert inlet.

The researchers looked at two alternatives for calculating the threshold velocity at which sediment will erode. The first was a method described by E.M. Laursen in his article "An Analysis of Relief Bridge Scour," published by the American Society of Civil Engineers in the *Journal of the Hydraulics Division* in 1963. The other was based on research published by C.R. Neill in the 1973 publication *Guide to Bridge Hydraulics*. Laursen's equation for the critical velocity is summarized in appendix C of the FHWA *Hydraulic Engineering Circular No. 18*.

Neill developed a family of curves for estimating critical velocities for sediments for varying flow depths with grain sizes ranging from 0.3

Scour, usually deepest near the corners at the upstream entrance, is evident after testing of this rectangular culvert model with 45-degree wing walls. The rectangle is surrounded by sediment that is lowest at the edges of the rectangle and peaks at its center.

Measured Representative Velocities



This chart compares measured representative velocities near the upstream corners of culverts to representative velocities computed based on potential flow theory. The plot shows that the measured velocities are approximately 30 percent higher than the computed velocities. *Source: FHWA.*

to 300 millimeters (0.01 to 11.7 inches). Neill defined the critical velocity as the flow velocity just fast enough to move the bed material and used a combination of field data and laboratory data to develop his family of curves. He used an equation similar to Laursen's to estimate the critical velocity for grain sizes greater than about 30 millimeters (1.2 inches). For a grain size of 0.3 millimeter, Neill used design equations developed from field data collected in stable, fine sediment canals in Pakistan for estimating the critical velocity. Having defined critical velocities for a grain size of 0.3 millimeter and for grain sizes greater than 30 millimeters, he hand-drew transition curves for grain sizes between 0.3 and 30 millimeters.

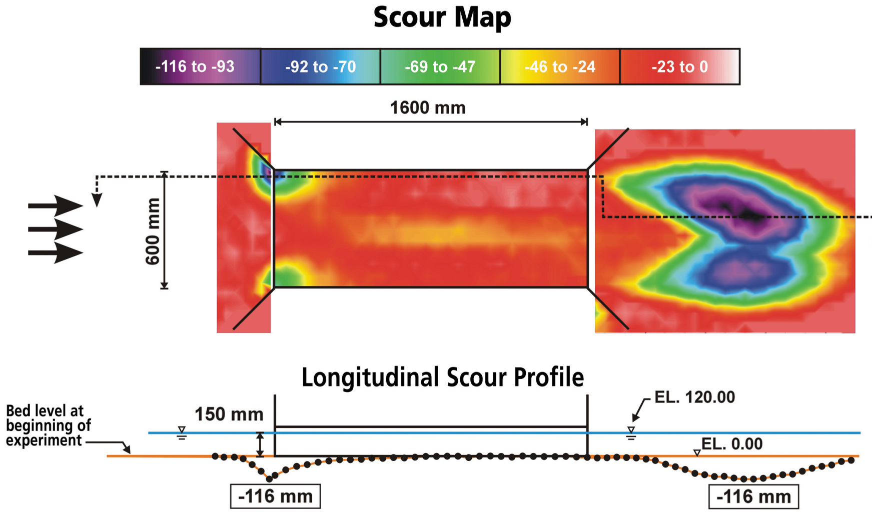
This research on scour in bottomless culverts revealed that the maximum scour depth, measured at the corners of the culvert, was always greater than the computed equilibrium depth, regardless of which equations for representative velocity and critical velocity were used. Thus, an empirical coefficient, similar to Chang's in ABSCOUR, was needed to explain the additional scour depth.

Model Setup

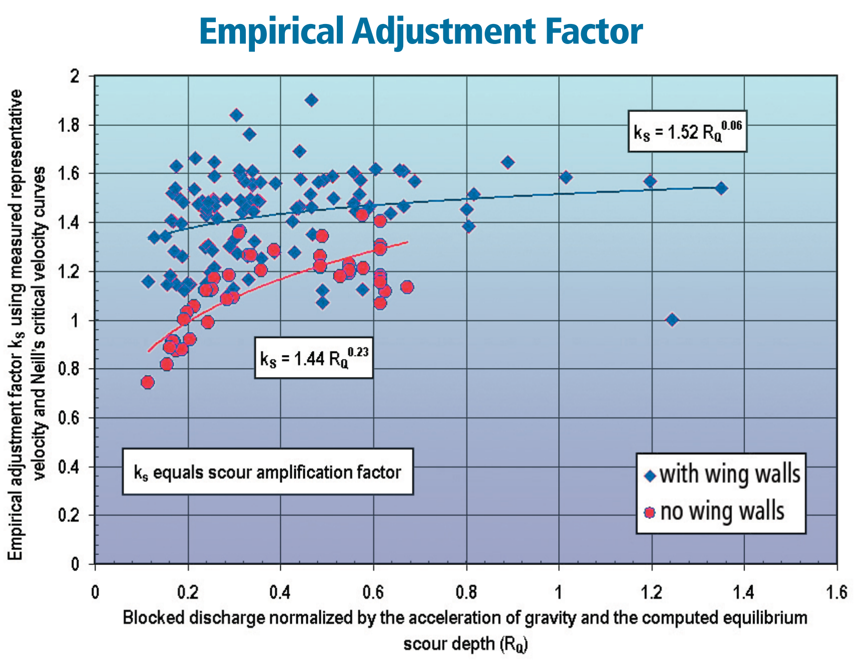
The experiments were conducted in a rectangular flume 21.35 meters (70 feet) long and 1.83 meters (6 feet) wide with a recessed section 2.4 meters (8 feet) long and 1.83 meters (6 feet) wide to allow for scour hole formation. A 9.15-meter (30-foot) approach section from the head box to the test section consisted of foam boards constructed 0.1 meter (4 inches) above the stainless steel flume bottom. The walls of the flume were constructed from smooth glass. The flume was set at a constant slope of 0.04 percent, and an adjustable tailgate located at the downstream end of the flume controlled the depth of flow. Flow was supplied by a pumping system with a maximum output rate of 0.3 cubic meter per second (10 cubic feet per second). An electromagnetic flow meter measured the discharge. A 13-millimeter (0.5-inch) spherical electromagnetic velocity sensor measured equivalent two-directional mean velocities in a plane parallel to the flume bed. Scour maps were generated using a laser distance sensor mounted on an automated flume carriage fitted to the main flume.

Three bottomless culvert shapes—rectangular, CON/SPAN, and CONTECH models—were constructed of Plexiglas® and tested for the first phase study. All three were evaluated with and without 45-degree wing walls. Marine-grade plywood was used for the headwalls and wing walls of the models. The models were mounted in the centerline of the flume.

For the second phase experiments, the laboratory model consisted of a rectangular bottomless culvert 0.60 meters (2 feet) wide and 0.15 meters (0.49 feet) high that was mounted in



This scour map and profile for a bottomless culvert with wing walls show that the deepest scour (darkest shading) was observed at the upstream corners and downstream of the culvert outlet *Source: FHWA.*



The two sets of data plots on the chart compare the scour amplification factor against an independent variable for a bottomless culvert model with wing walls and a model without wing walls. *Source: FHWA.*

the centerline of the flume. The culvert and headwall of the model were constructed of Plexiglas, and the wing walls were made from polystyrene foam.

Researchers conducted steady flow outlet scour experiments for approach flow depths ranging from 0.10 to 0.23 meter (0.33 to 0.75 foot) and approach velocities ranging from 0.07 to 0.16 cubic meter per second (0.25 to 0.57 cubic foot per second). The discharges to obtain the approach flow conditions varied from approximately 0.026 to 0.080 cubic meter per second (0.9 to 2.8 cubic feet per second). Particle size was set at 2.0 millimeters (0.08 foot) for the outlet scour experiments. The researchers tested several scour countermeasure configurations, including various wing wall angles, use of pile dissipators (vertical array of circular piles buried just below the channel bed), and the Maryland Standard Plan as a scour countermeasure design. The Maryland Standard Plan employs wing walls at the inlet and outlet of the culvert and lines the wing walls and the inside walls of the culvert with riprap.

Speed and Turbulence

Representative velocities near the upstream corners of the culverts were measured using prescour fixed-bed experiments. Researchers then compared the measured values to the values from the potential flow theory that allows derivation of theoretical velocity values. to derive a multiplier. A linear regression of the results shows that measured velocities for bottomless culvert applications are 1.28 times the velocities derived from potential flow theory.

The researchers performed extensive scour analysis using various combinations of equations for resultant velocity and critical velocity to determine the empirical adjustment factor to account for turbulence and vorticity at the upstream corner of the culvert. They used a laser distance sensor to generate scour maps through the entire bottomless culvert model and observed deepest scour at the upstream corners and downstream of the culvert outlet.

The researchers conducted a regression analysis for vertical face and wing wall entrance datasets and derived separate equations for the two datasets. They compared the scour amplification factor against an independent variable using the discharge blocked by the embankment normalized by the acceleration of gravity and the computed equilibrium scour depth.

Researchers found that the amplification factor is higher for a culvert without wing walls, indicating deeper scour compared to a culvert with 45-degree wing walls. Wing walls at the culvert entrance guide the flow more smoothly into the culvert, reducing turbulence and associated scour at the upstream corners.

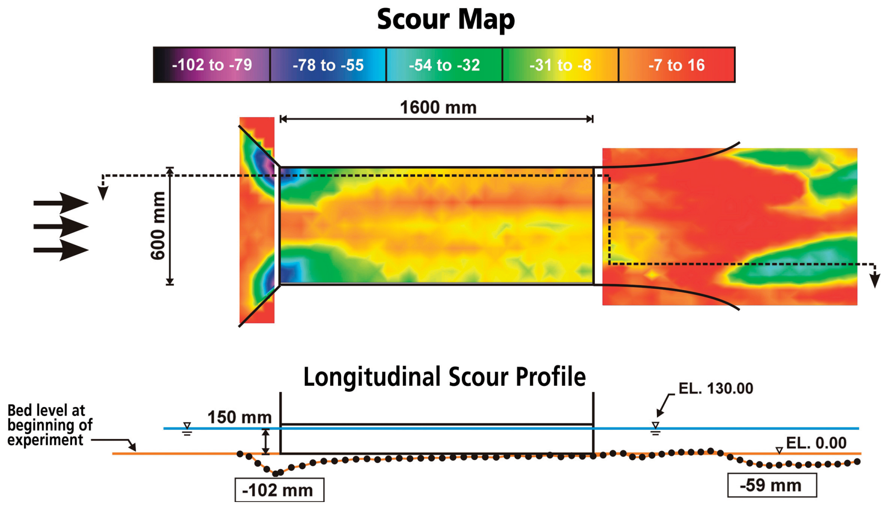
Traditionally, wing walls have been constructed with highway culverts to increase flow capacity. The inlet configuration is implicit in the inlet control equations and reduces the severity of erosion and scour of the channel and adjacent banks at both the inlet and outlet. The researchers investigated various inlet and outlet wing wall configurations under unsubmerged flow conditions to determine the overall effects of wall shape, length, and orientation on scour hole formation.

Experimental results indicate that turbulence is reduced, and "vortex shedding" caused by abrupt changes in pressure is almost eliminated with the use of a streamlined shape for the wing walls. In other words, the

Signs of significant scour appear at the downstream outlet of this model with 45-degree wing walls.

streamlined wall eliminates flow separation and decreases turbulence.

With the streamlined bevel, vortices do not propagate downstream, and the resulting turbulence is more evenly distributed and not concentrated in a single location. With sharp corners at the exit, the resulting abrupt change in pressure induces vortex shedding and increases scour depths. Researchers also tested 8-degree outlet wing walls, because streamlined wing walls may be impractical in the field. The 8-degree outlet wing wall results also revealed reduced turbulence and scour depth at the outlet.



For a bottomless culvert with a streamlined wing wall, this scour map and profile show a diminished flow separation and decreased turbulence, resulting in reduced scour at the outlet. *Source: FHWA.*

Significant Findings

Using the flow distribution at the culvert entrance to compute the primary scour depth component and adjusting with an empirical factor based on laboratory data appears to be valid for bottomless culverts. Culvert shapes tested in these experiments did not significantly influence the scour, but the entrance conditions did. The use of 45-degree inlet wing walls decreases the scour at the upstream corners considerably.

The experimental setup had some limitations. These experimental results are based on laboratory flume experiments with a flat approach cross section with uniform flow conveyance, which is not typical of field conditions. The experiments also were conducted under clear-water approach flow conditions with no sediment being transported into the culvert, which models a "worst case" condition.

These results have not been tested for field conditions; they are offered, however, as initial guidance for field applications. An anticipated next step is that the Maryland SHA will adopt the results as preliminary design guidelines and test them at field sites to decide whether the applications are reasonable.

The outlet scour experimental results showed the effects of using different outlet wing wall configurations at the outlet. Reducing the angle of the wing walls reduces the turbulent shear stress and thus reduces the scour depth created. The outlet experiments clearly demonstrated that outlet scour can be reduced substantially by using outlet wing walls with a streamlined shape. Test results from the 8-degree outlet wing walls revealed reduced turbulence and scour depth at the outlet. This is an encouraging finding, because wing walls with an 8-degree flare are easy to construct or order prefabricated, which may make this design more cost effective than the streamlined design.

"The basic advantage of bottomless culverts," says Kosicki, "at least from the perspective of environmental agencies, is the natural substrate in the bottom of the culvert that creates favorable conditions for fish passage. But natural substrate also can be simulated in circular culverts by burying them below the existing channel invert. When done properly, that offers the same advantage as bottomless culverts in terms of fish passage and additional advantages in terms of eliminating safety concerns due to scour that might exist in bottomless culverts."

Some advantages others have cited for using bottomless culverts, says Stan Davis, a consultant with Maryland SHA, "include ease and speed of construction, reduced road closure time, use of prefabricated elements instead of in-place casting, and wide selection of products to meet specific site criteria."

Kornel Kerenyi is a hydraulics research engineer in the FHWA Office of Infrastructure R&D. He coordinates hydraulic and hydrological research activities with State and local agencies, academia, and various partners and customers. He also manages the FHWA Hydraulics Laboratory. Kerenyi was previously a research engineer at a private company and supervised support staff in the Hydraulics Lab. He holds a Ph.D. in fluid mechanics and hydraulic steel structures from the Vienna University of Technology in Austria.

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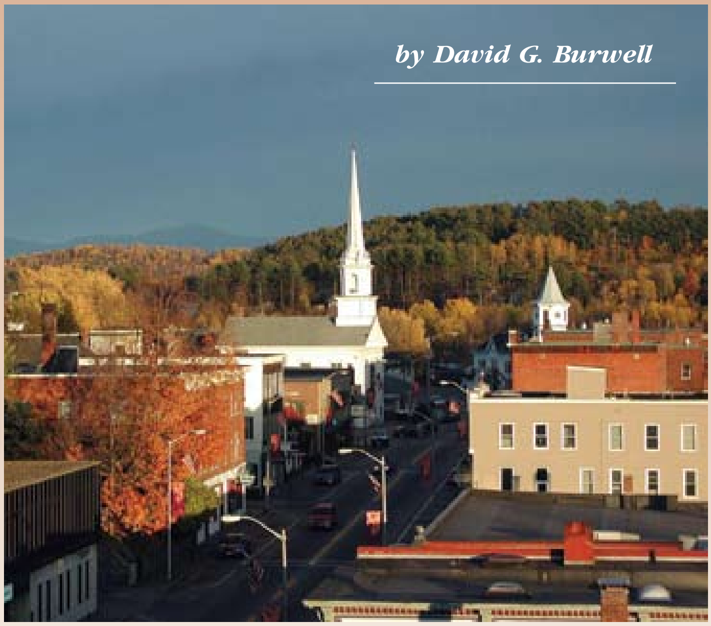
A Call To Action



by David G. Burwell

The citizens of New Hampshire write a long-range transportation plan to address congestion, land use, and related issues.

It was the spring of 2004, and New Hampshire Department of Transportation (NHDOT) Commissioner Carol Murray had a problem. Traffic was overwhelming the main streets and highways throughout her home State, threatening the small-town character that defines the quality of life in New Hampshire. Yet traffic was also the State's lifeblood, bringing tourists to its lakes and mountains and through its postcard-perfect village centers. "Transportation is the game board that everything else is played upon," says Murray, "but we were losing the game."

New Hampshire Community Foundation President Lew Feldstein had troubles of his own. For decades New Hampshire had been one of the fastest growing States in the Nation, causing the Community Foundation to identify growth management as central to its mission of strengthening a sense of community.

Feldstein had been a leader on several statewide growth commissions and was among the prime movers in a successful 5-year effort to double the State's inventory of protected open space to more than 100,000 acres (40,500 hectares) publicly acquired or put under private conservation easement. Yet it was not enough. "I realized," he says, "that for the time and money spent protecting 1 acre [0.4 hectare], we were leaving 1,000 acres [405 hectares] open for unplanned development." What the State needed was a more comprehensive approach.

(Above) The small-town character of New Hampshire is being overwhelmed by traffic and unplanned growth. Shown here is downtown Littleton, NH. *Photo: Project for Public Spaces.*

Murray had an idea to propose to Feldstein. It was time to update the State's long-range transportation plan. A strong believer in customer service as a key performance metric for her agency, she needed a new way to engage her customers in the plan. "I also knew that if we didn't connect transportation to land use, both would fail miserably," she says. Feldstein's Community Foundation was both a protector of community values and a statewide leader in land use planning. "I picked up the phone and asked him to chair a citizen panel to write the plan," she says.

"It was a shot out of the blue," says Feldstein. "It was not that transportation wasn't significant. It was, and is, at the core of growth and development. However, transportation decisions were made [independently from] the citizen-based processes that addressed growth and land use. Nor was transportation represented on any of the major commissions appointed by three different governors to look at statewide growth."

He had questions for Murray. Could the Community Foundation have an impact? Did it have the capacity to contribute, or would it be "window-dressing"? Feldstein went online and looked at 10 other State department of transportation long-range plans. "They were sleep inducing, full of jargon and acronyms," he says. "Most of them simply listed competing transportation objectives and declared that the plan would meet every one. Few included any tough decisions." He told Murray, "No."

Murray persisted. Feldstein pushed back: Will the Community Foundation's role be substantive? Will we be equal decisionmakers in the selection of citizen members? Will the panel include critics of NHDOT? Will the Community Foundation be provided independent consultant support separate from NHDOT's consultants? Will Murray and her leadership team be accessible? Will the plan be implemented by NHDOT? "Yes" was the answer on all accounts. After months of negotiations, including a direct meeting between Murray and the Community Foundation's board of directors, an agreement was reached. Murray and the Community Foundation mutually agreed on and impaneled a 24-member Community Advisory Committee (CAC).

Square-Dancing In a Broom Closet

As director of planning at NHDOT, it was Ansel Sanborn's job to explain the process to the members of the newly minted CAC, many of whom knew next to nothing about transportation planning, what a long-range plan is, how it is developed, and what it is supposed to do. Sanborn was mystified. The question was how to communicate the planning process, its connection to project development, and funding issues to people from such organizations as Easter Seals, the Society for the Protection of New Hampshire Forests, the Foundation for Healthy Communities, and the New Hampshire Municipal Association. Equally vexing, how to do this without boring the transportation industry members on the panel: the truckers association, rail and bus organizations, and the Safe Roads New Hampshire Initiative group? "For the first 3 months, nobody had any idea what we were talking about," says Sanborn.

Sanborn had an even bigger problem. "In previous long-range plans, when the plans were done, we shelved them," he admits. This plan had to be different. Not only were new customers involved, commitments had been made that this plan would be implemented. In particular, the charge that Murray gave the committee included the assignment to "establish strategic direction for future investment in, and management of, State transportation assets over the next 20 years."

CAC members included representatives of the Executive Council of the State of New Hampshire and both the State House and Senate transportation committees, groups that considered transportation policy and funding their exclusive domain. How to empower the CAC without offending the politicians?

Initially, Sanborn played it safe, sticking with presentations that explained planning cycles and project development processes without infringing on legislative prerogatives. They fell flat. Then he had an idea. "I realized," he says, "that to get people interested in transportation, you had to talk to them about something they were interested in."

He prepared a white paper that focused, not on system condition and level of service, but on social, economic, and environmental issues facing the State. The paper outlined some clear social problems such as the fact that 25 percent of the State's population does not have a driver's license. New Hampshire's population was also the fastest growing in New England, and the segment of population over 65 is growing. "What's going to happen when you can't drive anymore?" Sanborn asks. "That was an interesting question to them." NHDOT set up offline training sessions to educate CAC members unfamiliar with the transportation planning process and focused committee meetings on what the CAC wanted to talk about.

It worked. "Who cares about pavement?" asks Easter Seals President Chris McMahon. "People care about access. My people's basic needs are food, health care, and getting to a job. Survival access is the issue. Are people getting connected to the services they need to survive?"

The vetting of member concerns also helped the group to coalesce. "We got beyond the stereotypes of viewing members simply as representatives of a particular organization," says Municipal Association representative Maura Carroll, "to understand real transportation issues and needs of a variety of individuals and groups. The education process was tremendous."

And confusing. "The challenge of writing a citizen plan," says CAC member Cliff Sinnott, executive director of the Rockingham Regional Planning Commission, "is that, when you start talking to citizens about transportation, you can't contain the conversation."

Jim Jalbert, president of C&J Trailways®, an intercity bus company, has a more direct description of committee meetings: "It was like square-dancing in a broom closet. We kept bumping into each other's issues."

A Transportation Plan for the State

As NHDOT staff and consultants supplied information and case studies from other States on issues raised at committee meetings, the citizen team reached consensus on a fundamental finding: the need for a comprehensive vision for statewide growth and development.

"It became obvious to all of us," says Kathy Hersh, director of community development for the city of Nashua, "that transportation is not the goal. Transportation is a tool to get to the goal."

Equally obvious was that the tools needed to manage transportation were not all in NHDOT's toolbox. Committee member Bill Norton, a commercial real estate investor, concluded, "We have reached the end of our rope in trying to pave our way

NHDOT

Fast-growing freight traffic presents a challenge for streets in small New Hampshire communities like this one where a semi-trailer is negotiating a tight turn.

New Hampshire Charitable Foundation

CAC members: (front row, left to right) Maura Carroll, NH Municipal Association; Claire Monier, NH Housing Finance Authority; Nancy Girard, Conservation Law Foundation; Patti Carrier, NH Ball Bearing; Kathy Hersh, Nashua Community Development; Jane Difley, Society for Protection of NH Forests; Carol Murray, NHDOT Commissioner; (second row) Mill Duncan, Carsey Institute, UNH; Dave Juvet, BIA/Safe Roads NH; Jim Jalbert, C&J Trailways; Chris McMahon, Easter Seals; Bob Scully, NH Motor Transport Assoc.; Ray Burton, Executive Councillor; Lew Feldstein, NH Charitable Foundation; Chuck O'Leary, Former NHDOT Commissioner; George Bald, Pease Dev. Authority; Michael King, North Country Council; Senator Chuck Morse, Senate Transportation Committee. Not shown: Shawn LaFrance, Foundation for Healthy Communities; Steve Lewis, SLI Consulting; David Fink, Guilford Rail; Bill Norton, Norton Asset Management; Cliff Sinnott, Rockingham Regional Planning Comm.; Ed Smith, NHDOT Policy Director.

out of our transportation problems. We need to pay attention to how we can affect the demand side of the equation. That includes land use."

The committee findings reflected this view in the final plan. "Unless local land use decisions are better coordinated with transportation decisions, the amount of traffic on the State system will continue to accelerate," the plan concludes.

With freight traffic growing at about 3.5 percent annually, the committee also found that "we need to address freight from both the supply and the demand side." However, NHDOT's traditional role as a builder and manager of transportation infrastructure is ill-suited to this demand-side function. "Nobody's in charge of reducing the State's need to lay more pavement," says the Easter Seals' McMahon. "Somebody's going to have to be in charge of doing something about this."

Sanborn agrees. "The committee's product is not NHDOT's transportation plan," he says. "It is a transportation plan for the State of New Hampshire. Our job is to implement the plan where we can and to develop partnerships to advance the plan's goals when we can't."

Recognizing the importance of partnerships, the plan directs NHDOT to undertake three innovative initiatives. At the local level, it says, "design transportation solutions in traditional municipal centers and downtowns to fit the context of the community." At the regional level, it directs the agency to "build regional planning commission capacity to integrate transportation and land use planning," and to "develop multimodal corridor plans to better understand and coordinate transportation and land use." At the statewide level, it directs the agency to "develop a truly comprehensive statewide transportation plan that serves a broader vision for the State and to include other State agencies with resources to contribute in the development of the plan."

McMahon describes the partnership challenge in operational terms. She envisions partnerships to promote "vertical and horizontal integration," with agencies at the municipal level pooling resources to address common transportation problems (the horizontal axis) and then developing regional and statewide interagency partnerships to fill the gaps in their capabilities (the vertical level). "Start locally and roll it up," McMahon says.

The 900-Pound Gorilla

Under the leadership of Lew Feldstein, who was determined to produce a plan that set specific goals and policies to which NHDOT could be held accountable, the CAC focused its recommendations on 15 specific actions under the direct control of NHDOT. In addition to the partnership initiatives mentioned above, some of the more creative recommendations include the following:

- Increase local technical assistance, including the creation of cross-agency technical assistance teams to assist local planning; encourage coordination of local master plans with neighboring communities; and provide educational training on integrated transportation and land use planning. The teams would include staff from NHDOT and the Offices of Energy and Planning, Economic Development Division, the New Hampshire Department of Environmental Services, and the New Hampshire Department of Health and Human Services. Promote zoning that encourages traditional downtown development and redevelopment by promoting street connectivity, onstreet parking, and pedestrian-friendly environments. Reclassify main streets that are also State highways to remove them from minimum design speed requirements, as appropriate.
- Engage the private sector to help manage demand on the system by adopting policies such as flex time, telecommuting, and ride-sharing with guaranteed ride home policies. Supply incentives to businesses to provide private transit services and band together as transportation management associations modeled after the successful program sponsored by Dartmouth College and private partners in the Upper Valley region of New Hampshire.
- Adopt a "wellness" program approach to project development, funding small projects that, when combined with land use actions, can provide quick results and prevent small transportation problems from becoming big problems. Priority should go to projects that are "faster, better, and

more efficient" rather than "bigger, slower, and more expensive." With the State 10-year transportation funding plan being underfunded by at least 50 percent, projects must be prioritized to maximize overall societal benefits.
- Broaden citizen engagement in regional planning. Expand public outreach beyond traditional transportation stakeholders to seek out private sector, independent sector, and general customer engagement, such as the interests represented by the members of the committee itself.

Acknowledging the limited resources available, the CAC focused on recommendations that do not require a lot of new money. Says the Municipal Association's Carroll, "We find other ways to do things. Local governments can partner with the State to leverage private sector support."

About 28 percent of the State road system is under State ownership. The CAC concluded, "We need to address transportation as a system," not just the State road system but all roads and all modes, including services not under the control of NHDOT. This comprehensive approach requires attention to customer needs at all levels, including people who do not drive. "We count how many trucks and cars move because that is the only number we know how to count," says the Easter Seals' McMahon. "We can do better."

The CAC did not reach consensus on the key issue of funding. Although a majority of the committee agreed that New Hampshire needs more resources, a minority voiced the view that "we should learn to live within our means." With no income tax, no sales tax, and a State gas tax (19.6 cents) that ranks 26th highest among all States in total gas tax burden, those means are limited. Furthermore, gas tax revenues are constitutionally restricted to public highway use, not rail or transit. "Transportation funding is one of three 900-pound gorillas in the room," warned real estate investor Norton, "along with health care and education. We should deal with it."

The CAC also did not agree on the related issue of how to raise the new revenues that the majority of the committee members believe are needed. "Any discussion of transportation finance raises complicated economic, technical, and legal issues," the committee wrote in the plan. "Delving into these issues was not in our charge."

The CAC believed that financing is a fundamentally political issue because it involves the question of who benefits from, and who pays for, transportation services, an issue that was not in the CAC's area of expertise.

Significantly, the CAC voted to include minority views in the plan itself. This decision allowed dissenting opinions to be respected and publicly acknowledged, but also made consensus on the final report possible. "A commitment to respectful communication," says the Municipal Association's Carroll, "was key to our success."

Holding Everybody Accountable

After drafting its findings and recommendations, the CAC decided to do something bold. Rather than simply recruiting stakeholders to attend an NHDOT-sponsored hearing on the draft plan, the committee members decided to host hearings themselves, with NHDOT and its consultants listening, rather than presenting the plan. Transportation Commissioner Murray attended all nine meetings, which attracted more than 400 participants. "I heard a lot of concerns about transportation, from issues about health and obesity to finance to transit needs to land use," she says. "Listening is an important element of transportation planning. We as transportation practitioners need to do more of it."

The response from the public was positive—but skeptical. "Citizens asked two main questions," says Murray, "why am I here?" And "why do I care?"

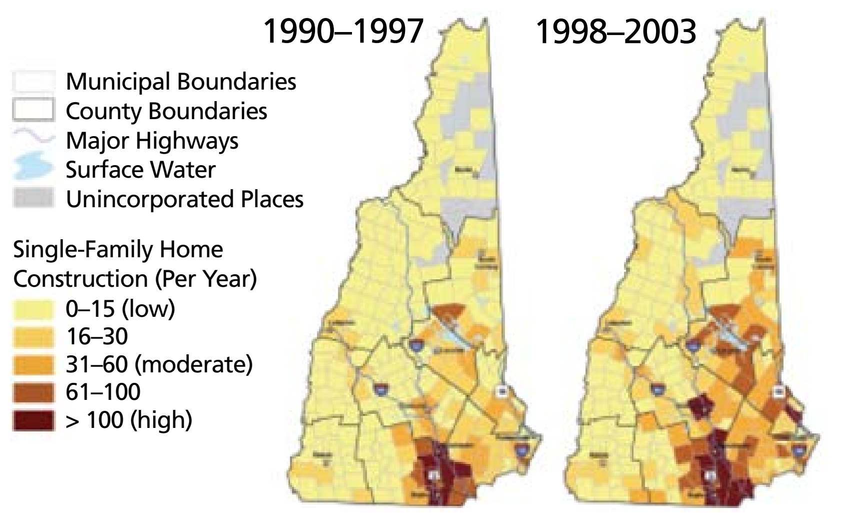
NHDOT's Sanborn adds a third most-asked question: "Is anything going to happen? Get back to us when you can show us that something has changed."

Murray adds, "It was an empowering process for all of us. For the first time, it enabled us to expand the conversation beyond transportation and discuss larger issues, such as health care, the importance of village centers, safe routes to school, and quality of life."

Regional planner Sinnott adds, "It turns out that the citizen long-range plan is not so much a problem-*solving* process as a problem *exploration* process. The conversation needs to continue."

When the CAC submitted its final report to Murray on June 9, 2006, she promised to present the agency response by the end of the year in a form that CAC members could take to the public, identifying

Land Consumption in New Hampshire, 1990–1997 and 1998–2003



Comparing the two maps shows that land consumption in New Hampshire is accelerating, as represented by the growing number of single-family homes built, on average, per municipality per year—that is, the increase in high-density areas. *Source: Society for the Protection of New Hampshire Forests.*

Citen Long-Range Plans: Lessons Learned

- Negotiate the terms of engagement upfront, especially the role of the citizen chair.
- Include a wide range of community interests on the panel, including critics.
- Expand the conversation to issues that citizens are interested in, even those over which the State department of transportation has little control, such as land use, transportation for the disabled, access to health services, and school-related transportation services.
- Foster a culture of respectful communication.
- Permit citizens to talk, professionals to listen.
- Provide background training for citizens coming in new to transportation issues.
- Allow for flexibility in selecting a process to produce the plan.
- Identify common values, encourage hard choices.
- Use plain English. Do not allow transportation jargon to impede communication.
- Connect the long-range plan to the project funding process.
- Provide independent professional support to the citizen panel.
- Invite citizen organizations to host public hearings and put transportation on the agenda of nontransportation organizations.
- Include minority views in the plan.
- Engage key decisionmakers in the deliberations rather than waiting until the report is completed.
- Hold all participants accountable for implementation.

who was accountable for making change happen. "We liked that," says the Easter Seals' McMahon, "We need a throat to choke."

A Call to Action

In December 2006 Murray, her staff, and the plan consultants met at the Community Foundation's conference room to present the agency's response to the plan. The news was mixed. Yes, the system is broken—especially the 10-year funding plan, which is really an 18- to 20-year plan and contains projects that exist only as placeholders. "But," Murray said to the CAC, "I need your help. This is a call to action."

In fact, the 10-year plan is developed by the regional commissions, with public input, and approved by the Executive Council and the legislature. The regional commissions, Executive Council, and the legislature all have representatives who serve on the CAC.

"We have to either raise the bridge (raise more money) or lower the water (reduce the number and cost of projects)," says Michael King, director of the North Country Council, a regional planning commission. "We are all part of the problem, and we all need to contribute to the solution."

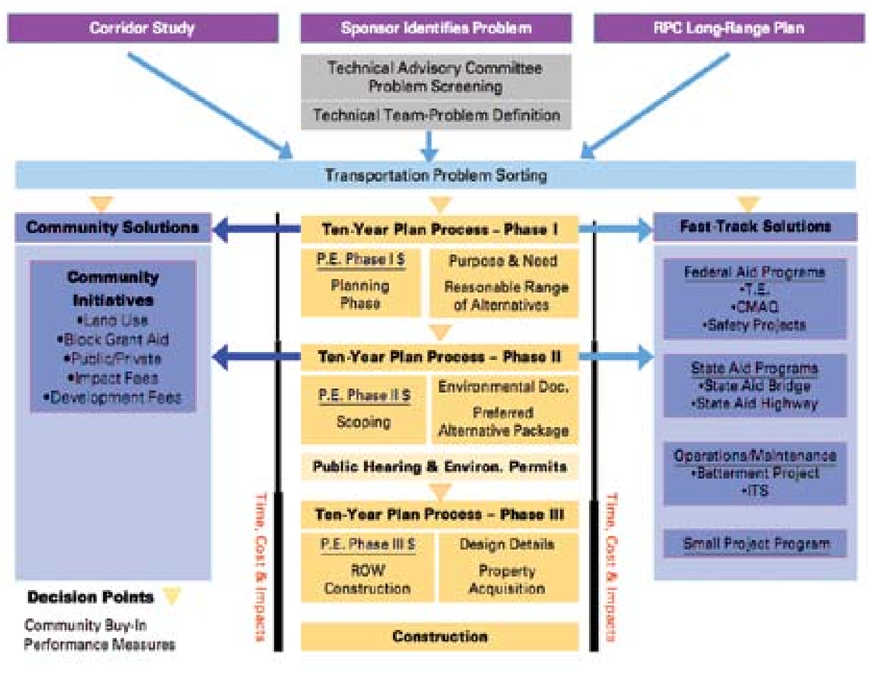
NHDOT was good to its word. "We hear you," said NHDOT's Sanborn, who presented the following specific agency commitments to implement the citizen plan:

First, NHDOT agreed to advocate for change in the statewide planning process to address both transportation *and* its broad societal impacts. NHDOT also agreed to engage other State agencies in transportation plan development and to include the CAC plan as the transportation section in the State Development Plan, an effort being led by the Governor's Office of Energy and Planning.

Second, NHDOT agreed to provide new planning and technical assistance to municipalities and regional commissions on the transportation elements of their plans. It also will provide training to agency staff, regional commissions, and municipalities on how transportation projects can promote a sense of place and improve community cohesion—and NHDOT will integrate these values into the project development process. This assistance will promote system "wellness" by addressing smaller problems quickly rather than waiting until they become big problems, will include demand side as well as supply side solutions, and will advance transportation and land use partnerships of particular interest to the CAC.

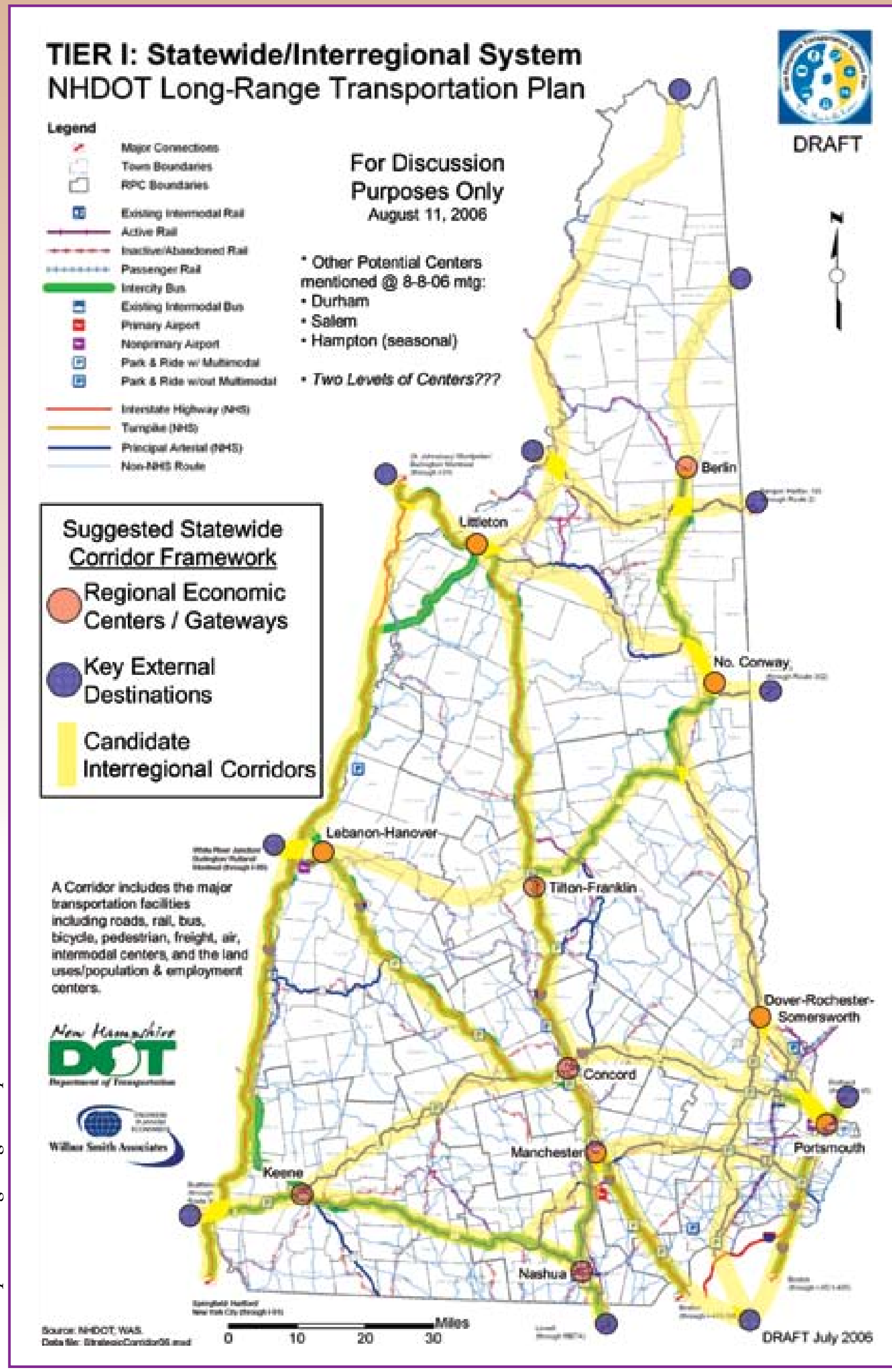
Third, NHDOT will work to reform the 10-year plan to adopt the CAC's preferred investment strategy. This strategy includes dividing projects into components, funding only what can be implemented during the 2-year planning and programming cycle, and measuring priorities against societal goals. NHDOT will require project sponsors to frame the specific problem addressed and explain why the

NHDOT's New Project Development Process



Under NHDOT's new project development process, land development and transportation decisions work in parallel to preserve capacity and keep the road system healthy. *Source: NHDOT.*

This map shows the corridors identified by NHDOT for statewide, multimodal, integrated transportation and land use planning. Transportation improvements will focus on supporting growth around economic activity centers, gateways, and other destinations, while protecting corridors from strip development through coordinated land use planning and access controls along major routes such as I–93 and I–89, State Route 16 along the eastern spine, and Route 101 along the southern tier.



New Hampshire Long-Range Transportation Plan

funding requested is the most efficient response to the problem.

Fourth, NHDOT will adopt a statewide planning framework for corridor management that (1) addresses interregional and intraregional travel needs; (2) is multimodal, including strategies that use State highways to accommodate transit services such buses, vanpools, and other public transportation services; (3) adopts a "fix-it-first" approach to the transportation system; and (4) supports statewide ridesharing programs by partnering with municipal and regional transportation management associations.

Fifth, NHDOT will make public involvement a fundamental aspect of all transportation planning, including training staff in communication and listening skills, and providing all partners with access to common data on transportation trends, impacts, alternatives, processes, and financing.

Will it work? Time will tell. Certainly, Murray has raised expectations by supporting this call to action and by laying down markers for NHDOT accountability.

"This plan gets NHDOT involved in community planning," says regional planner Sinnott. "I hope NHDOT has the resolve to stick with it."

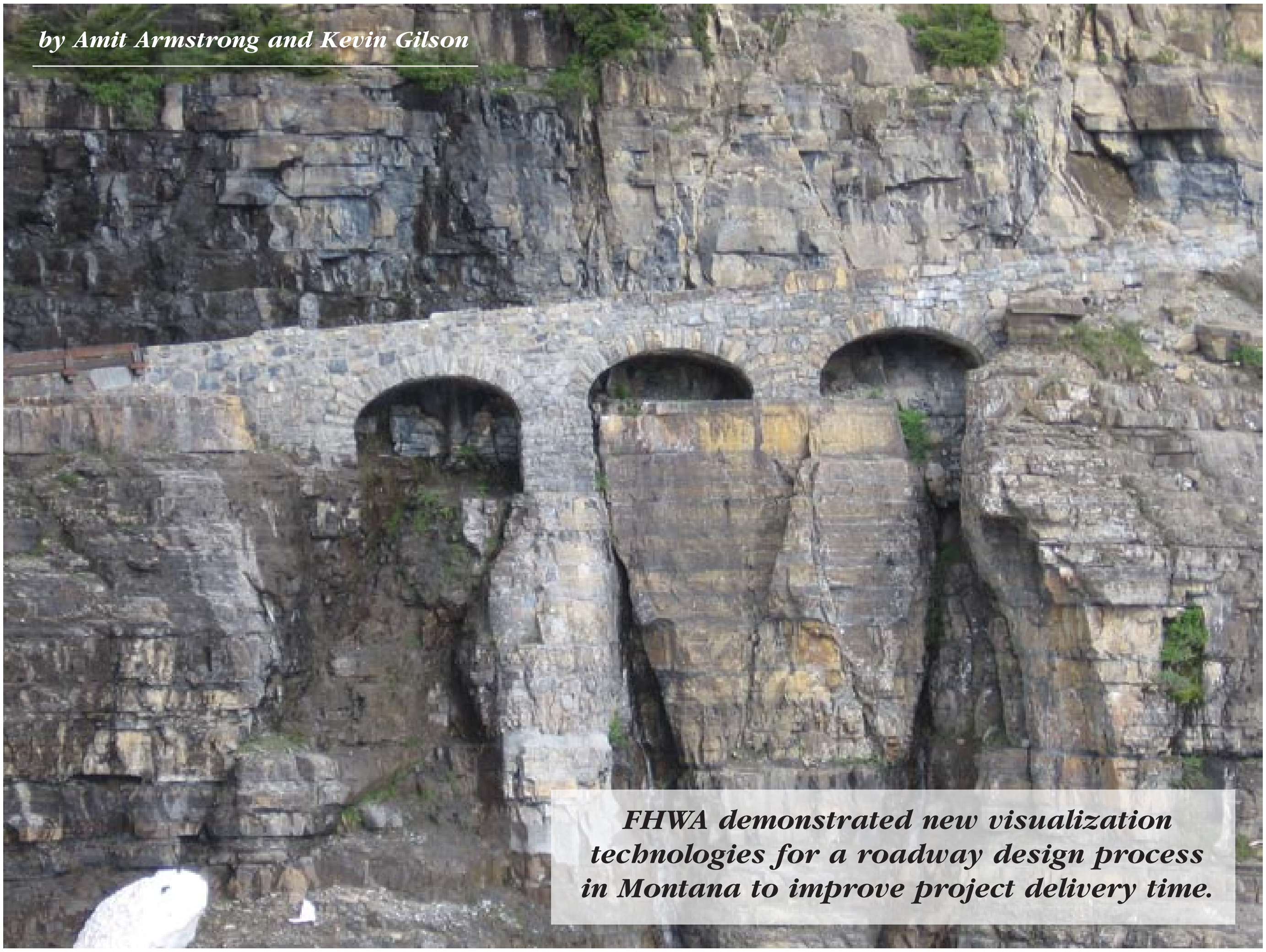
Feldstein has a similar wait-and-see attitude. "For the first time, New Hampshire has a transportation plan that speaks to community-wide transportation needs, not just those served by NHDOT. But implementation is not automatic. We are at the very beginning of moving to a customer-driven process."

One thing is certain: The customers now have a clear plan of action and an agency willing to take responsibility for its piece of plan implementation. But this will happen only through partnerships, involving mutual commitments between State legislative and executive leaders, other State agencies, regional and metropolitan planning organizations, municipalities, citizens, and the private sector. In this sense, everybody has a continuing role to play in the success of this pioneering effort in citizen-led transportation planning.

David G. Burwell is a transportation consultant for the Project for Public Spaces, a nonprofit firm in New York City that provided consulting support to the Citizen Advisory Committee. Burwell is cofounder and former CEO of Rails-to-Trails Conservancy and a former CEO of the Surface Transportation Policy Project. He has degrees in government from Dartmouth College and law from the University of Virginia.

The full text of the New Hampshire Citizen Long-Range Transportation Plan and the NHDOT response to the plan are available online at www.nhtranplan.com. For more information, contact David Burwell at 301-767-0871 or dgburwell @comcast.net.

Virtual Highways—A Vision of the Future



by Amit Armstrong and Kevin Gilson

FHWA demonstrated new visualization technologies for a roadway design process in Montana to improve project delivery time.

A picture is worth a thousand words.

Successful completion of a highway construction project depends on actively engaging stakeholders during the planning phase, adequately addressing their issues during the design phase, and clearly conveying the incorporated changes throughout the construction phase. Traditionally, engineers and planners have used two-dimensional (2–D) paper maps (plan and profile sheets and cross-section drawings) to represent the design and construction process. Paper maps fail to engage stakeholders during the planning phase, however, as the maps lack visually appealing three-dimensional (3–D) information. Lack of stakeholder engagement during that phase often results in a cascade of design changes and project delays, as issues raised by stakeholders during construction are incorporated in the project.

Design visualization tools are effective in conveying the real-world 3–D information to transportation stakeholders and the public. When a project involves complex engineering issues, these tools can be used to show proposed designs and to run a series of "what if" scenarios. Interaction and engagement with stakeholders enables them to provide constructive feedback, understand technical and engineering issues, and be involved in the decisionmaking process.

(Above) Shown here is the famed Triple Arches Bridge on the Going-to-the-Sun Road in Montana. FHWA used renovation of the road as a case study in the use of design visualization technologies.
Photo: Kevin Gilson.

Design visualization is the simulated representation of a concept and the contextual impacts of a new or rehabilitated highway. The visualization encompasses anything from a simple shaded view within a drawing, to a photosimulation, or even an animated 3–D model. In the past, use of design visualization techniques was limited to large or complex projects due to high cost and computing requirements. The advancement of computing power and availability of moderately inexpensive software, however, makes design visualization tools widely accessible to designers.

The Federal Highway Administration's (FHWA) Federal Lands Highway Division (FLHD) is working to integrate design visualization as a mainstream tool to address design issues and communicate with stakeholders. "The goal is to facilitate the application of simple, low-cost techniques and tools that provide a high relative payback while supporting context sensitive solutions to design problems," says Mark B. Taylor, design discipline leader with FHWA's Central Federal Lands office.

As part of the FHWA technology deployment program, the Western Federal Lands Highway Division (WFLHD) is working on implementing these innovative, emerging, and underutilized design visualization technologies on projects for Federal land-management agencies such as the National Park Service (NPS), U.S. Forest Service, and the U.S. Fish and Wildlife Service. The goals of this technology deployment project are to assess the effectiveness of design visualization tools for a typical situation, evaluate the cost of visualization relative to the complexity of the project, and develop a framework for utilizing these techniques through in-house staff or contracted services.

During an earlier effort, a Web-based design visualization guide (www.efl.fhwa.dot.gov/manuals/dv) was developed for FLHD. This guide documented available design visualization tools and presented a workflow so that the design staff could use such techniques more routinely. The current effort also explores the tools that are not currently available to FLHD staff and are used only by specialized design visualization consultants.

Going-to-the-Sun Road: A Case Study

Currently, WFLHD and the NPS are cooperating on the rehabilitation of the scenic Going-to-the-Sun Road, a historic and civil engineering landmark roadway in Glacier National Park in Montana. The challenge and complexity associated with the design and reconstruction of this roadway prompted WFLHD to use this project as a case study for evaluating the role of design visualization technologies in improving project delivery time. (For a full description of the Going-to-the-Sun Road rehabilitation, see "Saving a National Treasure" in PUBLIC ROADS November/December 2006.)

The reason WFLHD chose the Going-to-the-Sun Road as a case study for design visualization is because the rehabilitation covers a wide range of project issues: road rehabilitation, visitor use improvements, public information, information technology improvements, and transit. The project's final environmental impact statement and subsequent record of decision provided a clear direction for rehabilitation, including a comprehensive mitigation program to minimize impacts on the park and its visitors. One directive called for the development of a new transit system and the integrated deployment of an intelligent transportation systems technology to support the construction, a new transit system, alternate routes, and traveler-related park information.

The Going-to-the-Sun Road project also was optimal for the case study because the rehabilitation involved and affected multiple stakeholders, including WFLHD, the NPS, consultants, park concessionaires, the local tourism industry, gateway communities, and the public. Various changes and improvements to the Going-to-the-Sun Road itself and proposed transit stops needed to be shown to these diverse audiences with special attention to the scenic and historic qualities of the contextual environment.

Project Applications For Visualization

At the start of the project, the team identified three applicable areas for visualization. The first involved visually capturing the existing conditions along certain parts of the Going-to-the-Sun Road. The second required organizing available data into a more accessible and presentable format, and the third involved simulating proposed design alternatives visually.

The design visualization team used and demonstrated several tools for each of these areas to explain proposed designs for the project. (See "Computer Tools Used for Visualization" on page 28 and "A Comparison of Tools" on page 29.)

Capturing Existing Conditions

Documenting existing conditions included simple photography and video. Digital cameras made this easier and more cost effective than in the past. Digital images were used with 3–D model renderings and digital paint techniques to produce photosimulations of proposed changes. For this initiative, the visualization team used Apple® QuickTime® Virtual Reality (QTVR) to produce panoramas for several locations where transit stop changes and improvements were proposed. The images produced a good record of

Shown here are two screenshots of a lidar point cloud with color image data applied to the points; the left half of the image shows the color image data, the right the raw point cloud. The scan was taken at a tunnel, the West Portal, of the Going-to-the-Sun Road.

Computer Tools Used for Visualization

A significant limitation in incorporating visualization into the design process is the wide variety of computer applications and tools used at a typical visualization firm. A key to incorporating design visualization techniques into a design practice involves the commitment to acquiring the tools and applications and enabling staff to learn those applications.

An experienced design visualization practice will have most of the following types of tools: computer aided design/drafting (CADD), geographic information systems (GIS), image processing, three-dimensional (3–D) modeling and rendering applications, and presentation tools. For simplicity, many different types of applications are placed into these five categories. Photography and video also are usually an integral part of design visualization productions.

CADD Tools. Most roadway design projects are developed in a CADD system, and the best way to handle the data is in the native application. For roadway projects, 3–D surfaces can be generated by the design application. Some examples of applications for highway design in the United States include Bentley Systems' MicroStation, Geopak, and InRoads. Accessing design data and preparing for export to other applications can be handled in the MicroStation software. Two important techniques that were demonstrated for the Going-to-the-Sun Road initiative were the 3–D Adobe Acrobat PDF exporter in the current version of the MicroStation software. The other was the conversion of CADD data into overlays for Google Earth Pro mapping service.

GIS. These tools allow different types of data, such as aerials and digital elevation models (DEMs), to be aligned into a consistent coordinate system projection, usually that of the design project. For most roadway projects, a State Plane coordinate system is used for the design work. GIS tools allow data in other coordinate projections to be converted into State Plane coordinates for alignment with design data. A few of the tools that are accessible to design staff are the following:

Global Mapper is a cost-effective tool that allows import, viewing, re-projection, and export of raster images, DEMs, and vector data. This tool was used extensively for the Going-to-the-Sun Road initiative to convert aerial imagery and DEM data into coordinate system alignments that could be inserted into the CADD design files and into Google Earth.

Google Earth Pro mapping service is a software tool that allows the user to see where data are relative to an aerial view of the surrounding context. Google Earth Pro was used in the project as the viewing tool and reference database for all of the existing information collected for the case study: aerials, DEMs, and CADD data. It was used also to visually link to site photography, LIght Detection And Ranging (lidar) scan data, and each of the visualizations produced.

Image Processing. Visualizations are presented as images and usually will involve some postprocessing using an image-based application. Digital painting is an essential part of photosimulation and is used for creation of texture maps—images applied as materials to the surfaces of digital 3–D models. Animation production requires video editing and compositing applications. The project team commonly used Adobe Photoshop® and Corel® Paint Shop Pro® X.

3–D Modeling and Rendering Applications. Visualization will almost always involve some kind of 3–D model for the proposed condition and sometimes the surrounding context. Materials, lighting, and animation are added to a 3–D model using these tools, and then virtual cameras allow the creation of views of the 3–D model. An investment in modeling and rendering software is probably the biggest hurdle to adoption of visualization, due to the cost of the software and the lengthy learning curve. Staff must be dedicated to using the tools close to full time to benefit fully from the time spent learning the software and maintaining a skill level with applications that are changing and improving rapidly.

A certain level of rendering capability is built into MicroStation software, and these tools are more realistic for adoption by highway designers. The learning curve is shorter, and there is an advantage to using the native CADD tools that the designs are being developed in. The roadway designs are turned into 3–D surfaces using MicroStation Geopak tools, and then materials and lighting are added to the 3–D model. Renderings can be generated directly from MicroStation viewports. The renderings can be matched to existing site photos, and image processing software is used to produce photosimulations of proposed projects. This is the technique currently in use by FLHD staff.

Presentation Tools. Included under this category are tools that help in the creation of visualization presentations. Included are applications such as Microsoft PowerPoint presentation software. For the Going-to-the-Sun Road project, a number of other tools were used, including Apple QuickTime Virtual Reality (QTVR) digital media software format to document existing conditions. QTVR files, when viewed in the QuickTime player, were more interactive and descriptive of the environment than static images. The QTVR files were "stitched" from 18 original still images captured on a special tripod head. The image format enabled the viewer to pan and zoom around in a 360-degree view of the scene.

Real-time interactive "game" engines were used in this project for a few presentations. Real-time presentations enabled viewers to move around in and interact within a 3–D environment. This freedom of movement within a model enabled viewers to see what they want from the viewpoint that was most interesting to them, rather than a passive view presented in standard animation where the views and camera path are fixed. Objects, or "layers," in the model could be set to switch on and off interactively, which allowed a direct comparison between alternative model elements from any selected viewpoint.

The performance of real-time models is directly related to the amount of 3–D detail and lighting quality that can be rendered out quickly enough for real-time interactivity. Because of limitations with video and computer system random-access memory (RAM) on standard computers, models used for interactive playback must be optimized for size and number of images employed for representation of the materials in the scene.

the existing conditions. The images also were used in some locations to produce panoramic photosimulations of proposed improvements.

Another new technology demonstrated in the study was ground-based LIght Detection And Ranging (lidar) scanning. A lidar camera captured a series of 3–D range values by measuring time of flight for a laser beam to return to the camera several times per second as the lens was moving. This resulted in a set of "XYZ" values, or point cloud, that was translated to a coordinate system that matched the project computer-aided design/drafting (CADD) data. Locations of several of the individual points were measured and turned into usable CADD point or line data. Tools for automating conversion of the point cloud to usable CADD data are evolving rapidly, and this technique will likely become a cost-effective means of capturing existing 3–D project information.

Technology from InteliSum™, Inc., also was used on this project. InteliSum products incorporate color data into the lidar range data, or point clouds. Each 3–D point from the cloud had several color points, or pixels, associated with it. The tool included a viewing environment that facilitated seeing the data from any view as points or surfaces, either with solid colors or the photographic image applied. This technique was similar to moving a camera around the original 3–D environment, and it proved invaluable for a historically and visually significant project such as the Going-to-the-Sun Road because 3–D and photographic data were captured together in a georeferenced environment (meaning the data are referenced with geographical coordinates).

The InteliSum viewing application enables the user to measure positions for point data and to export sets of point positions for use in CADD applications. "What is interesting about this tool is that other 3–D model types can be inserted into the viewing environment and used to create interactive visualizations showing proposed changes," says Tim Case, project manager with Parsons Brinckerhoff, Inc., the FHWA contractor that produced the design visualizations for the Going-to-the-Sun Road project. Future enhancements to this application will make it more compatible with other point cloud processing software, thus making it useful for capturing existing survey-quality 3–D data while serving as an interactive visualization tool.

Organizing Project Information

A goal of the initiative was to demonstrate a visual, accurate, and collaborative viewing environment that organized and provided intuitive access to project data. Google™ Earth Pro™ mapping was used for this case study project, but several other tools could have been used to achieve the same result, such as the National Aeronautics and Space Administration's (NASA) World Wind or Microsoft® Virtual Earth™. These tools provide an environment where users can easily "fly" virtually anywhere on Earth with aerial imagery draped over 3–D terrain data as the base environment. Any data that can be projected in a standard georeferenced coordinate system can be overlaid on this base environment. In the project's early stages, the Google Earth mapping service's

This screenshot shows a texture-mapped 3–D model of a bus inserted into the color-mapped lidar point cloud. The lidar scan is of the West Portal Tunnel on the Going-to-the-Sun Road.

A Comparison of Tools

In this table, the visualizations demonstrated in the case study are rated by relative level of production effort and relative software investment cost. They are rated also by the type of expertise needed for efficient use of the tool; a cost-effective tool is not always an easy tool to use economically. Staff may need specialized training or certain inherent skills. The decision on what level of investment to make in integrating visualization into design will depend on the people who will be responsible for production. Dedicating staff full time to visualization production ensures that their skills will be up to date and improve over time.

Most highway designers already are equipped to use the first three technologies (in yellow), and all of these tools are relatively similar in effort required. FLHD staff members currently are producing photosimulations and CADD renderings with animation from MicroStation software. To produce 3–D Acrobat PDF files would require using the newest version of MicroStation software. Renderings from CADD can be used for communicating design issues, cut/fill slopes, and roadway layouts, especially to a technical audience who understands the application renderings and illustrations.

Photosimulations require a little more skill but bring a higher level of realism suitable for less technical audiences. The amount of skill needed and effort spent painting in details is directly related to how much realism is desired for communicating key issues. More complex issues or environments, more controversial projects, and less sophisticated audiences drive the need for more realistic and complex visualizations.

Professional schools are beginning to offer more extensive visualization curricula, so design visualization specialists with the right combination of technical and creative skills will become more available.

Type of Visualization	Level of Effort	Software Investment	Skills Required
Photosimulation	Low	Medium	Significant creative and some technical
Rendering from CADD Design files	Low	None	Some technical
Interactive 3–D PDF model	Low	None	Some creative and some technical
Editing 3–D PDF model with Acrobat Professional	Low	Medium	Some creative and some technical
Google Earth with CADD Overlays	Low	Medium	Some technical
QuickTime Virtual Reality	Medium	Medium	Some technical
QuickTime Virtual Reality Photosimulation	Medium	Medium	Significant creative and some technical
Rendered 3–D model	High	High	Significant creative and significant technical
Animation in 3–D model	Very high	High	Significant creative and significant technical
Interactive textured models	Very high	High	Significant creative and significant technical
Lidar captured 3–D models	Very high	High	Significant technical and some creative

Image data ©2006 Google Earth™ mapping service and Europa Technologies

This screenshot of the Google Earth Pro mapping service model of the Going-to-the-Sun Road includes a high-resolution aerial image overlay. Spatially referenced CADD data from project design files were inserted into the model.

aerial data for Glacier National Park was too low in resolution to recognize the roadway. The NPS had high-resolution georeferenced aerials, however, that were imported directly into the model as overlays. CADD data from the design files also were exported in georeferenced format and imported as vectors into the Google Earth mapping service model. Station locations along the road centerline could be selected, and the viewer would "jump" to that location in the model environment.

Location markers, called *placemarks*, were inserted into the Google Earth mapping service environment. These placemarks could be labeled, contain notes, and be linked to other files. These placemarks were used in the Going-to-the-Sun Road design visualization project to link to site photos, site QTVRs, project documents, and lidar scan locations. A user could open a placemark and reference a QTVR panorama taken from the location of the placemark in the environment. Placemarks also were used to link to other visualizations produced for the case study.

The models produced in these aerial imagery-based presentation tools can be placed in a shared network environment where a project team has access to the same files, or the models can be packaged and distributed for viewing by individuals on their own.

Standard Visualization Techniques

Other than shaded views produced directly in a CADD environment, the technique that is most familiar to designers for representing proposed improvements is photosimulation. 3–D surfaces for the new roads and grading could be generated using the CADD application and superimposed over existing site photos. With a little work in a digital paint application, the road could be made to look more realistic. Cars and people could be clipped from other images and inserted into the view. For the level of realism obtained, photosimulations were a very cost-effective solution.

Rendered 3–D models were more flexible because they could be viewed from any angle and could include animated elements to give a view more life and realism. All the elements in the scene had to be modeled, and for large projects this could be quite cost prohibitive. Models could be developed, rendered, and even animated entirely in the CADD application in which they were produced. Obtaining the level of realism and quality that could be achieved with rendering applications was difficult, but for projects that do not warrant significant effort, this could be a cost-effective solution. This approach would require some specialized skill or training on the designer's part.

Locations such as the Going-to-the-Sun Road were exceptionally challenging because of the environment's high level of visual quality. Landscaping, curvy roads, and rock surfaces were some of the most difficult features to show and represent well in a model. An area along the Going-to-the-Sun Road called The Loop, the only switchback along the entire route, was chosen as a location from which a highly detailed 3–D model would be produced. The site had many design issues that lent themselves to visual study: a transit stop, major trailhead, parking, and a sharp curve. Several different types of visualizations were produced and compared for this area.

One demonstrated use for the model involved evaluating clearances and visibility with proposed transit vehicles. Because the site model was built from the road design data, and the bus built to scale from the

A 3–D model of a proposed bus was modeled and used for evaluating a new paint scheme. The bus was used in renderings of proposed transit facilities and for checking clearances in 3–D using ground-based lidar scan data.

manufacturer's specifications, the two could be used together to analyze and illustrate these issues. The bus model was used in combination with the ground-based lidar-captured data to look at clearances at portals and overhanging rock-face locations along the Going-to-the-Sun Road.

New Visualization Tools

Interactive models enable the user to navigate to views that they want to see, as opposed to passive animations or renderings that limit the viewer to fixed views. This flexibility makes these tools useful for both planning changes and presenting designs to a varied audience, such as decisionmakers and the public. Objects in the model can be switched on and off to allow direct comparisons between alternatives. The tools for producing interactive content are becoming more commonplace, and computers today are equipped with sophisticated graphics capability. These improvements will lead to more use of real-time presentations for design visualization.

Adobe® Systems Inc., has incorporated interactive 3–D capability into its Adobe Acrobat® 7 Professional software's Portable Document Format (PDF) file format. The Acrobat 7 Professional software allows the conversion and importation of several different 3–D file formats and has the ability to include the 3–D models in other kinds of documents, such as Microsoft® PowerPoint® presentation software slideshows and Microsoft® Word documents. The recent versions of MicroStation V8 software include an exporter for the Acrobat 7 Professional software PDF format, allowing for direct conversion of 3–D design files into interactive presentations. The format supports texture-mapped surfaces and objects. This tool can be used to view and share project designs. Designers would need to build surfaces and objects in 3–D from their design files to create these presentations, but that involves a relatively small amount of additional work using highway design software applications such as Geopak® or InRoads.

The video game industry has prompted the development of efficient tools for producing interactive content. Many of the tools are based on the modeling and rendering applications used for design visualization, allowing for a single 3–D model to be used in several ways: rendered views, animation, and interactive presentations. The model that was developed around the Going-to-the-Sun Road's Loop area was used to create a game-like immersive presentation. The user

A highly detailed 3–D model was produced for The Loop area of the Going-to-the-Sun Road. The model was used to evaluate transit stop designs, parking, and pedestrian circulation improvements. Varying numbers of cars and people can be placed in the model to demonstrate safety issues with pedestrian visibility in parking areas during busy usage times.

This 3–D model of the site, in combination with accurate 3–D models of the shuttle buses shown here, can be used to check clearances, both horizontally and vertically, along the roadway.

could move around the model to any location and look around. The model included predefined viewpoints and the ability to switch between the existing and proposed conditions, including transit and parking improvements. The main challenge for this type of model was representing the park's scenery as realistically as possible. The plants and rock surfaces needed to be modeled with the least geometry and image information as possible to allow for smooth and effective real-time playback.

Reactions to the Visualizations

The resulting Going-to-the-Sun Road visualizations were presented to Glacier National Park staff currently involved with the transit design work, including Gary Danczyk, project manager, Mitigation, Going-to-the-Sun Road project, who is managing the effort for the Glacier National Park. After seeing the visualization work, he said, "We need to be using these images in our strategic planning meetings for the transit center and bus stops." The presentations will be used for further design evaluations and presentations to other Glacier National Park staff and to the public. The plan is to use some of the mapping tools developed to help visually track and illustrate bus and station locations for a transit control center. The case studies also were presented to the WFLHD design staff responsible for the rehabilitation work, with the goal of using some of the tools for further design studies.

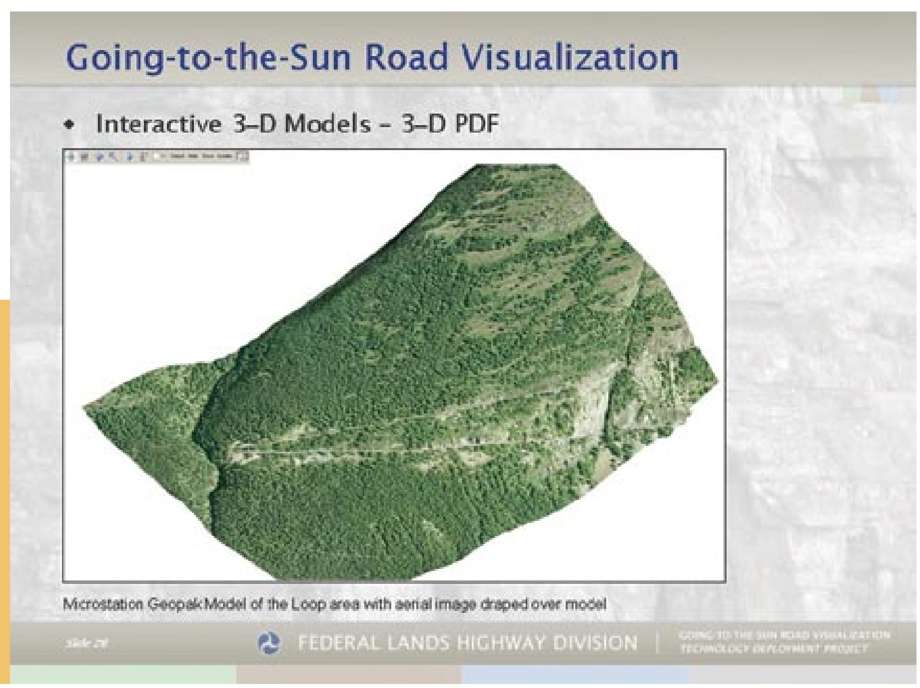
The Going-to-the-Sun Road visualization study was presented at the Transportation Research Board's 5^{th} International Visualization in Transportation Symposium and Workshop in October 2006. During a panel discussion, titled "Employing Visualization Organizationally," many attendees confirmed the challenge of finding appropriate staff with the right skills to champion adoption of visualization in a design organization. Another recurring panel theme was the common perception that adopting visualization would be cost prohibitive. The symposium's proceedings are posted at www.teachamerica.com/viz/viz2006.html.

Creativity or Technical Skill?

A key consideration in finding the right people to help integrate visualization into the design process is having an understanding and awareness of the difference between the visualization artist's creative and technical skills. Some of what makes visualization successful is creative ability, which often can be more valuable than technical proficiency. Visualization technologies vary in their requirements for creative or technical skills. More sophisticated and realistic visualization will require staff members who are interested in, or willing to be trained in, both the creative and technical sides of visualization. Furthermore, they need to be able to include a true representation—unbiased and factual—of the existing and proposed conditions in order to produce a meaningful involvement of the stakeholders.

Summary

For the Going-to-the-Sun Road project, a number of design visualization tools were used to explain



A screenshot of an interactive 3–D Acrobat PDF inserted into a PowerPoint presentation. The model can be panned, rotated, and viewed from any direction while running the slideshow. The model uses a surface created from U.S. Geological Survey elevation information combined with project survey elevation information. An aerial image has been draped over the 3–D surface. It was exported directly from MicroStation V8 software.

An interactive 3–D model of The Loop area, shown here with proposed improvements to the parking and the transit stop. The model was produced with a high level of detail and uses game engine technology for interactive navigation and the ability to switch between existing and future components.

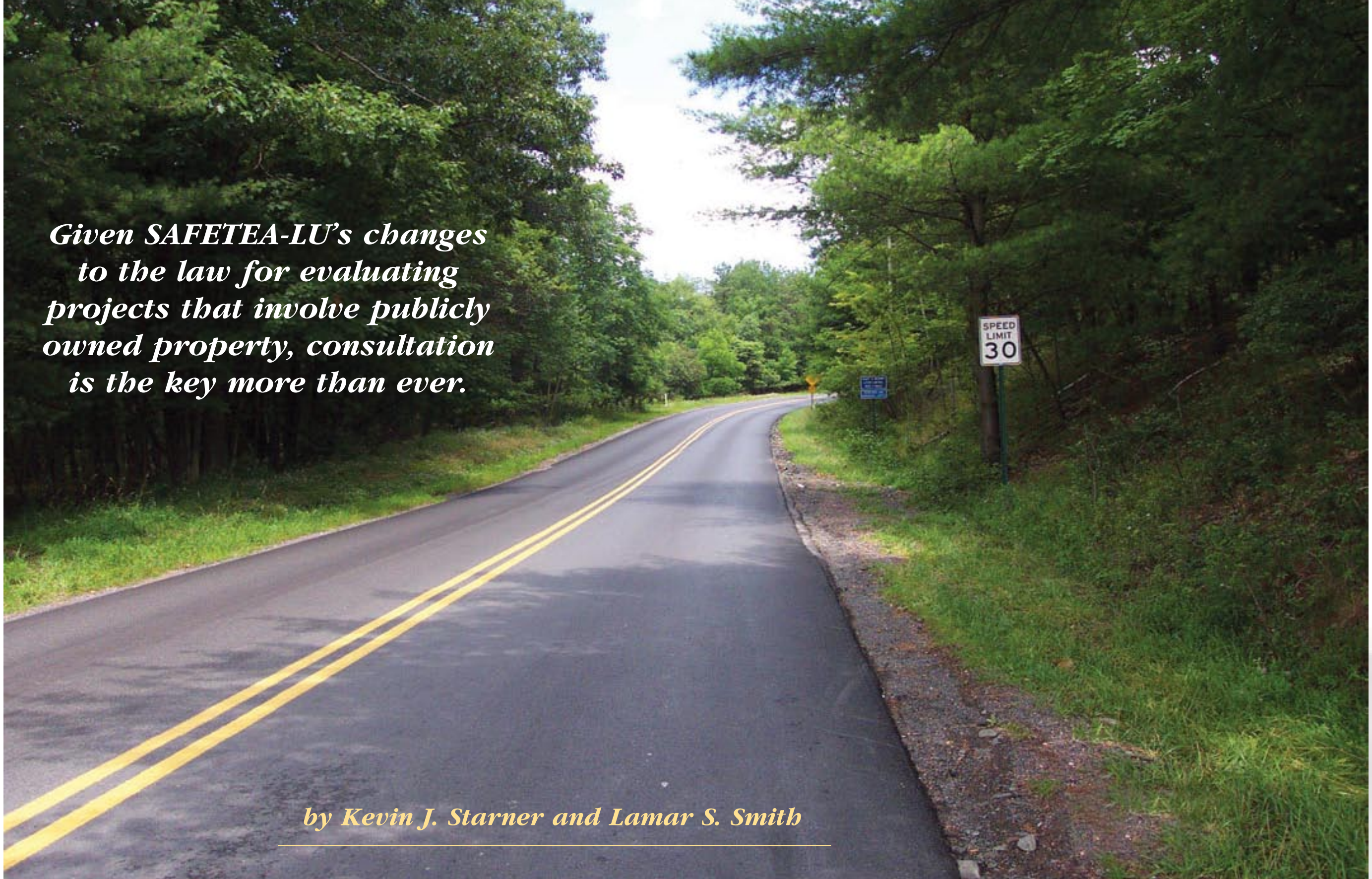
the proposed designs for several locations. For each unique situation, a specific design visualization technique was selected. The cost and level of effort were compared for various design visualization techniques. The resulting visualizations were presented to the design team and transportation stakeholders, both technical and nontechnical, during several sessions. The consensus opinion of the project design team was that these tools clearly communicated technical aspects of the project and context sensitive design approaches when compared to traditional design plans. "It is a great communication tool to explain various aspects of the project to all stakeholders," says Keith Wong, project manager with FHWA.

The design team was able to communicate the engineering challenges and proposed solution for The Loop to the NPS. The contextual model clearly communicated the visual aspects of the design to the NPS landscape architects. The use of visualization expedited the decisionmaking process to resolve critical engineering issues with the NPS and other stakeholders. In their quest for ontime delivery, designers and managers for the Going-to-the-Sun Road project expressed interest in applying the visualization tools for the planning and design of various phases of this project. "A fully-animated model of proposed transit stop designs at other locations on the road, such as Logan Pass, would be invaluable to show the proposed improvements to our stakeholders and arrive at a consensus design solution in a short timeframe," says Kristin Austin, project design team member with WFLHD.

Amit Armstrong, Ph.D., P.E., is a technology deployment engineer at FHWA's WFLHD in Vancouver, WA. He has been with FHWA for 5 years, coordinating deployment of new, innovative, emerging, and underutilized technologies in design and construction of roads on Federal lands projects. He has more than 15 years of experience in numerical simulation and visualization of natural systems and is a licensed professional engineer. Armstrong received his doctorate in civil engineering from Texas Tech University in Lubbock, TX.

Kevin Gilson has more than 20 years' experience in producing digital design visualization for transportation engineering projects. He is a senior professional associate at Parsons Brinckerhoff, a transportation consulting firm. For the last 2 years, he has been the design visualization specialist responsible for exploring new technologies for the design, planning, and presentation of large-scale civil engineering projects. Gilson obtained a master's degree at the University of California at Berkeley, CA.

For more information, contact Amit Armstrong at 360-619-7668 or amit.armstrong@fhwa.dot.gov or Kevin Gilson at 303-390-5932 or gilson@pbworld.com.



Given SAFETEA-LU's changes to the law for evaluating projects that involve publicly owned property, consultation is the key more than ever.

by Kevin J. Starner and Lamar S. Smith

Coordinating Section 4(f) Compliance

(Above) Roadway improvement projects that use public property must undergo USDOT evaluation and approval. On this section of Pennsylvania State Route 2001, the narrow travel lanes and lack of shoulders do not meet minimum requirements for a rural major collector. *Photo: Kevin Starner, Skelly and Loy, Inc.*

Federally funded transportation projects that involve the use of Section 4(f) property (publicly owned public park, recreation area, or designated wildlife and waterfowl refuge land or significant historic property) must undergo a formal evaluation and approval process that can be long and complex. Transportation use of these properties is subject to the requirements of Section 4(f) of the U.S. Department of Transportation (USDOT) Act of 1966. The law is complicated and has a number of substantive requirements. But a stronger emphasis on careful coordination with all stakeholders—even though not specifically required by the original law—can reduce stumbling blocks during the process and help protect these important resources.

As part of the development process for Federal transportation projects, compliance with 4(f) requirements typically is evaluated during the National Environmental Policy Act (NEPA) decisionmaking phase, concurrent with other environmental and cultural resource studies.

During this stage, agency coordination, public involvement, and other outreach activities have the greatest potential to influence the outcome of a project. This need for coordination may be particularly true for the Section 4(f) evaluation and approval process, which relies a great deal on consultation with the officials who have jurisdiction. Although Section 4(f) does not require public involvement, public opinion can be important to the officials with jurisdiction and may influence their concurrence during the NEPA process.

"We like to say that coordination should happen 'early and often,'" says Colleen M. Brown, P.E., a project development engineer in the Highway Quality Assurance Division, Bureau of Design, Pennsylvania Department of Transportation (PennDOT). "That means coordination with all parties, including PennDOT, the Federal Highway Administration (FHWA), the public, and the officials with jurisdiction over the Section 4(f) resource," she adds.

The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), enacted in 2005, the most recent Federal transportation law, contains a Section 4(f) de minimis (minor) impact provision. SAFETEA-LU emphasizes the importance of coordination with the officials with jurisdiction because it requires their written concurrence in USDOT's determination of no adverse effects on the activities, features, and attributes of the Section 4(f) property before making the de minimis impact finding.

The Section 4(f) Requirements

Before the SAFETEA-LU change in de minimis evaluations was enacted, Section 4(f) (as amended and codified in 49 U.S.C. §303 of the USDOT Act of 1966) covered all evaluations of transportation projects requiring the use of 4(f) property. The law stated that the Secretary of Transportation may approve a transportation project that will use 4(f) property only if there is no prudent and feasible alternative to using that land, and only if the program or project includes all possible planning to minimize harm to the park, recreation area, wildlife and waterfowl refuge, or historic site resulting from the use.

The Section 4(f) process involves an analysis of avoidance alternatives (no reasonable alternative to the use of 4(f) property) and an assessment of least harm. These requirements are triggered regardless of the type or size of the project, NEPA, class of action (categorical exclusion, environmental assessment, or environmental impact statement), or the USDOT administration involved in the project. Regardless of the Section 4(f) involvement, coordination with the resource officials is necessary in practice to comply fully with Section 4(f) requirements.

Karyn Vandervoort, environmental program manager in FHWA's Pennsylvania Division office, says that coordination actually needs to go one step further. "To coordinate is merely to bring together," she says. "Now more than ever, due to changes in Section 4(f), consultation is key. To consult is to engage and consider the input of others. Consultation occurs throughout a project's development, and all the players should have a role." She points out that a lack of consultation can result in partial or incorrect information and poorly completed applications, hindering the process.

The Individual Section 4(f) Evaluation Process

Project compliance with Section 4(f) requirements is documented through the development and circulation of a comprehensive written evaluation. These Section 4(f) evaluations can be lengthy and complex documents.

Normally an evaluation includes several elements: a general overview of the proposed project, a summary of the project purpose and need, a detailed description of the subject Section 4(f) resources, an analysis of project alternatives (including those that totally avoid the Section 4(f) resources), a synopsis of the project coordination with the officials having jurisdiction over the subject Section 4(f) resources, and a concluding statement as to which project alternative will result in the least harm to the subject Section 4(f) resources.

Individual Section 4(f) evaluations must be circulated a minimum of 45 days for review by the U.S. Department of the Interior, the U.S. Department of Agriculture (if applicable), the U.S. Department of Housing and Urban Development (if applicable), and the official(s) with jurisdiction over the Section 4(f) resources. Following this 45-day review period, the draft Section 4(f) evaluation is revised (if necessary) and submitted to the appropriate USDOT agency for a legal sufficiency review.

The final Section 4(f) evaluation is not approved until it is found to be legally sufficient. The intent of this review is to ensure that the evaluation and project record adequately and accurately reflects consideration of the Section 4(f) requirements and

Kevin Starner, Skelly and Loy, Inc.

This face-to-face meeting of project designers is an efficient way to facilitate coordination for a Section 4(f) project, enabling the participants to share engineering drawings, maps, and proposal documents. Written correspondence, telephone conversations, field views (formal meetings in the field), and site visits also are acceptable.

Typical Individual Section 4(f) Evaluation

- General overview
- Summary of project purpose and need
- Detailed description of Section 4(f) resources
- Analysis of project alternatives
- Synopsis of project coordination
- Concluding statement—describing which alternative will result in least harm to 4(f) resources

(The review period is a minimum of 45 days.)

provides evidence of compliance. Legal sufficiency is an important component of the Section 4(f) evaluation process, as Section 4(f) compliance historically has been one of the most litigated aspects of the process of developing transportation projects.

"You need adequate support information to make the Section 4(f) determination successful," Vandervoort says. "Figures, mapping, pictures, and documentation of consultation are all important. It doesn't have to be verbose, just poignant and relative."

In Pennsylvania, she adds, "FHWA uses several different types of checklists to document the Section 4(f) determination. These forms seem to expedite the process—indirectly they tutor the preparer on what information is necessary for FHWA to make the determination."

Programmatic Section 4(f) Evaluations: An Alternative

As a procedural alternative to the preparation of an individual Section 4(f) evaluation, certain transportation projects are eligible for the application of a programmatic evaluation. Programmatic Section 4(f) evaluations offer a streamlined and more efficient process to Section 4(f) compliance than individual 4(f) evaluations. Programmatic evaluations do not need to be circulated for the 45-day review period or submitted for a legal sufficiency review. A programmatic evaluation also provides greater flexibility in the level of documentation that is required.

For a project to be eligible for the application of a programmatic Section 4(f) evaluation, it must meet certain criteria as specified in one of the existing five programmatic evaluations (see www.environment.fhwa.dot.gov/projdev/4fnspeval.asp for more details). In general, programmatic Section 4(f) evaluations can be applied to certain types of transportation projects with minor uses of 4(f) property. Eligible projects also must meet certain scope requirements. FHWA is responsible for determining the applicability of programmatic Section 4(f) evaluations at the project level. Currently, projects eligible for the application of a programmatic evaluation fall under the following five categories:

- Projects that involve minor taking of property from public parks, recreation areas, or wildlife and waterfowl refuges
- Projects that involve minor property takes from historic sites
- Projects that involve the use of a historic bridge structure
- Independent bikeway and walkway construction projects
- Projects that have a net benefit to a Section 4(f) property

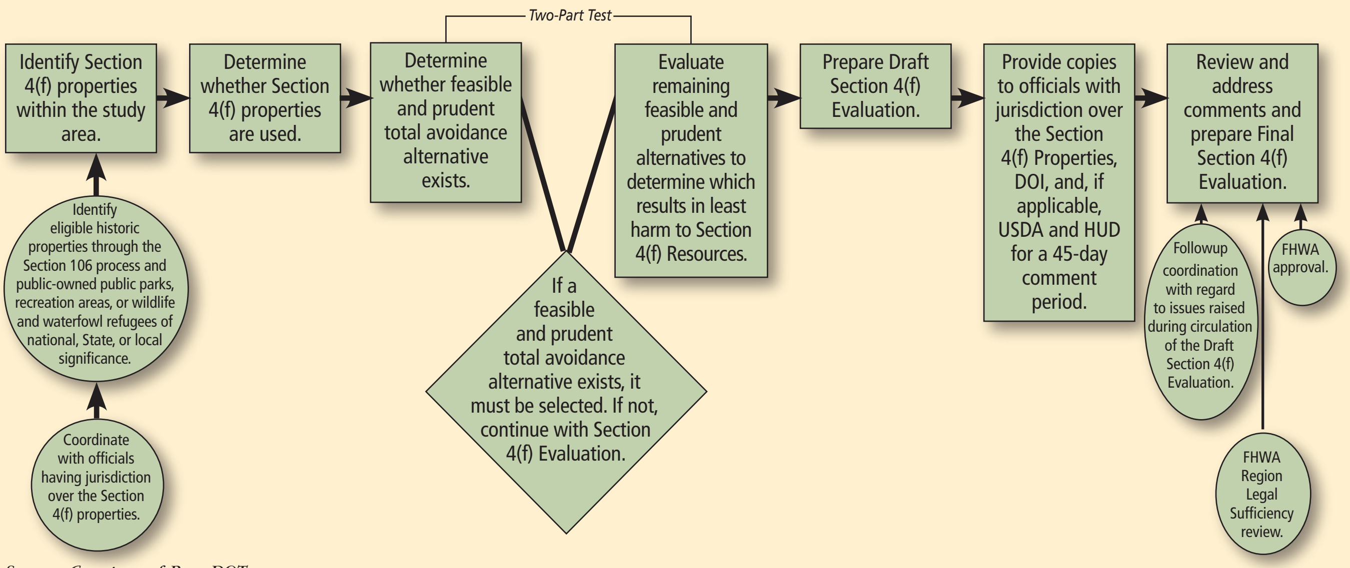
De Minimis Impact Finding

SAFETEA-LU amended the existing 4(f) law to simplify the processing and approval process for those projects that have only a de minimis impact on a public land resource. The SAFETEA-LU streamlining measure is the first substantive change to the Section 4(f) law since its adoption in 1966. The basic premise of this change is that once a project is determined to result in a "very minor" impact, an analysis of avoidance alternatives is not required, and the Section 4(f) evaluation process is considered complete. It is important to note that the de minimis impact finding is contingent upon written concurrence from the officials with jurisdiction. Therefore, coordination is key to achieving the de minimis impact finding.

Advantages of Coordination

As described above, Federal transportation projects can have varying

Section 4(f) Process

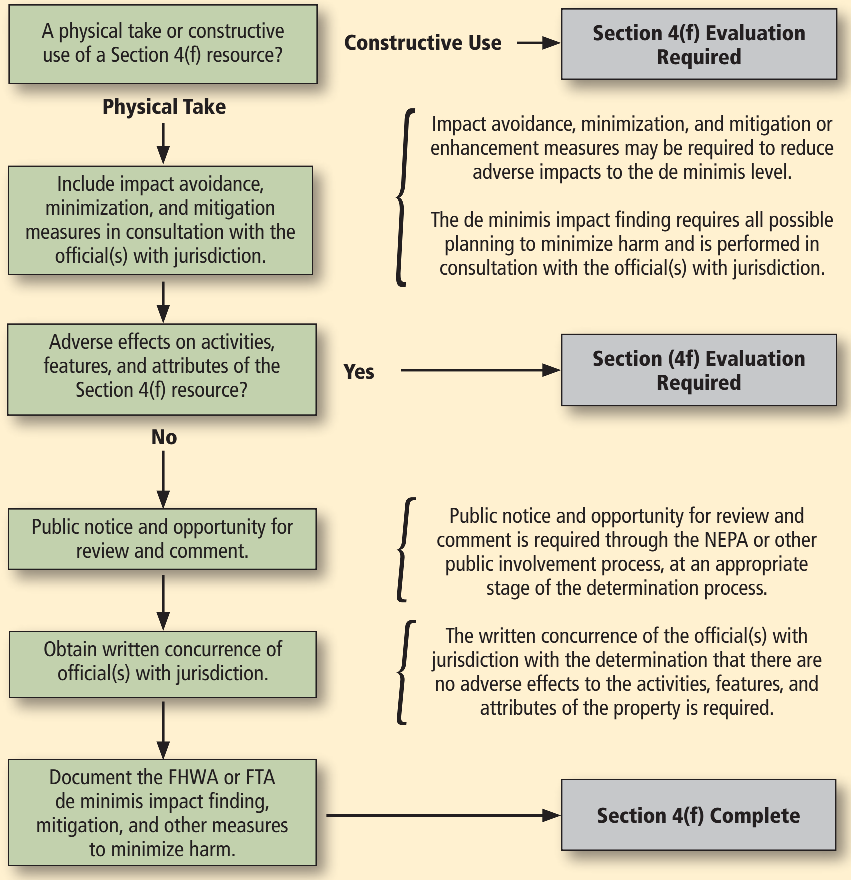


Source: Courtesy of PennDOT.

degrees of involvement with different types of Section 4(f) resources, and the level of analysis and documentation may vary accordingly. However, regardless of the type or use of Section 4(f) property, coordination with the officials with jurisdiction is an important and necessary part of the Section 4(f) evaluation process. In addition to being required early in the determination of a property's significance and the applicability of Section 4(f) requirements, coordination can aid greatly in the overall development, acceptance, and approval of a project.

Early and frequent coordination with the officials with jurisdiction can lead to the identification and resolution of problems and issues that could otherwise delay the development of a project. In a similar manner, coordination with the officials can, and indeed should, result in the identification and implementation of mutually acceptable mitigation measures to minimize harm. As such, coordination with the officials with jurisdiction can be beneficial not only in terms of project streamlining, but also in resource protection.

Suggested Process for Determination Of Section 4(f) De Minimis Impacts



Source: FHWA.

Stages of Coordination

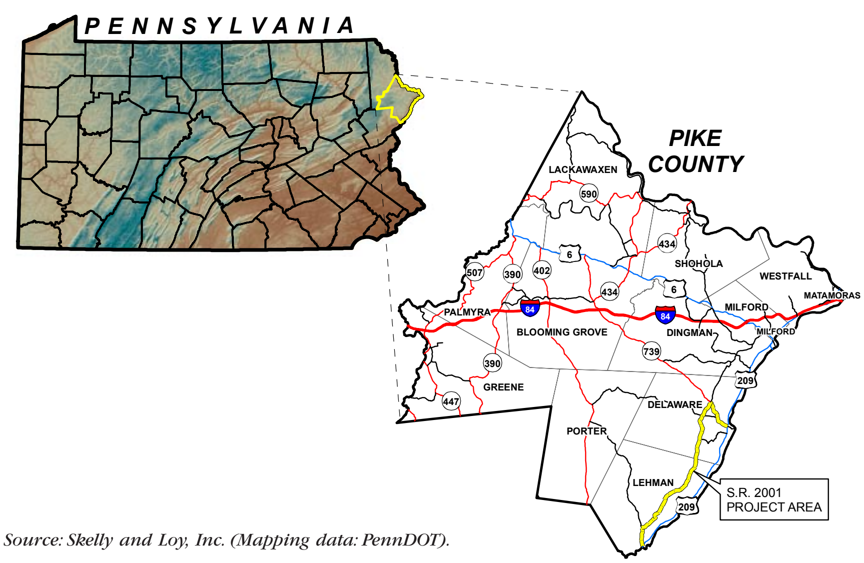
Coordination with the officials with jurisdiction can occur at various stages of the Section 4(f) evaluation process. First and foremost, coordination with the officials should be conducted at the outset of a project. This is true for two different, but equally important reasons. Initially, the officials with jurisdiction should be consulted to identify resources accurately, delineate appropriate boundaries, and assess the significance of the subject Section 4(f) resources. In this capacity, this first round of coordination should provide sufficient information to determine whether the resource in question is in fact eligible as a Section 4(f) resource. The second primary function of this first round of coordination is to inform the officials that a transportation project is planned for the general proximity of the resource.

Following the development of project alternatives or the identification of a preferred project alternative (depending on the size and scope of the project), the transportation team developing the project should initiate a second coordination effort with the officials who have jurisdiction. The primary purpose of this second coordination stage is to ensure that the project development team accurately identifies and assesses the proposed project's impact(s) on the subject Section 4(f) resource and identifies opportunities to avoid and minimize harm to the resource. Again, this second coordination effort serves a dual function. In addition to accurately assessing impacts, the transportation team provides information to the officials who have jurisdiction over the proposed project's impact on the subject Section 4(f) resource.

From this point, the coordination process can go any number of directions. The net effect or outcome, however, should be the identification of mutually acceptable minimization and mitigation measures to offset or balance the project's use of the subject Section 4(f) resource. The project team should work with the official with jurisdiction to determine who from that entity or agency is the correct representative for consultation and correspondence. Once the person is identified, it is best to work directly with that person to avoid potential communication gaps. Written concurrence from the officials who have jurisdiction on the assessment of project impacts and the proposed mitigation or enhancement measures is typically a desired, if not required, outcome. This written concurrence is required, however, for projects that are determined to have only a de minimis impact.

It is important to note that this coordination process is not prescribed or predetermined by the Section 4(f) law. The process is merely representative of what a typical or customary coordination process may entail. Similarly, the method or avenue of coordination (that is, written correspondence, telephone conversations, field views, site visits, meetings) is at the discretion of the project development team. It is not uncommon for a single project to involve a combination of these methods.

State Route 2001 Project Location Map



Source: Skelly and Loy, Inc. (Mapping data: PennDOT).

Coordination efforts in the Section 4(f) evaluation process can produce positive outcomes for both the project and the resource when conducted effectively. A 21-kilometer (13-mile) Pennsylvania roadway improvement project requiring the use of publicly owned land from a national recreation area and an associated programmatic Section 4(f) evaluation offer a case study to demonstrate the applicability of this concept.

Pennsylvania Case Study

The Milford Road improvement project is located in Pike County, which is in the northeastern part of the Commonwealth of Pennsylvania. The project involves reconstructing an existing two-lane roadway to improve safety and to meet current design criteria for shoulder and travel-lane width, and horizontal and vertical curvature. Implementation involves the use of property from the Delaware Water Gap National Recreation Area.

Given the use of a Federal recreational resource, the project was coordinated with the U.S. Department of the Interior's National Park Service (NPS). The coordination efforts conducted with NPS were a key factor in achieving environmental clearance for the project.

Sharon Okin, PennDOT District 8-0 environmental manager, points out that Pennsylvania begins the project design process with a "scoping" field view to discuss preliminary alternatives and potential environmental impacts with careful coordination. "Early in the project design," she says, "having the manager of the park or recreational area present at the scoping saves a lot of time in determining whether the property is protected under 4(f) and in identifying the significant aspects of the resource.

"Similarly, she adds, "we have State cultural resource archeological and historical properties professionals at scopings to determine the potential of having an eligible property present and the effect of the project. These professionals have the opportunity to work with the designers in the field to discuss avoidance and minimization measures as well as context sensitive design. These efforts can lead us to a "no effect" or "no adverse effect" determination that allows us to apply the de minimis finding."

Okin also strongly recommends the use of checklists to assure smooth sailing through the evaluation and approval procedure. "The checklists developed by FHWA and PennDOT set up a standard format for documenting the absence of 4(f) resources, temporary use, de minimis use, or programmatic finding. Having this standard format makes the information more complete, better organized, and easier to review and approve."

In 2001 PennDOT, in cooperation with FHWA, initiated preliminary engineering studies for improving sections 401 and 402 of State Route 2001 (Milford Road). These preliminary engineering studies focused on reconstructing a 22-kilometer (13.5-mile) section of Milford Road from its intersection with State Route 0739 in Delaware Township south to its intersection with U.S. Route 209 at Bushkill. The need for this project was based on the existing roadway's substandard travel lane and shoulder width and horizontal and vertical curvature.

Initial Coordination

Preliminary investigations of the project area revealed the presence of three resources protected under Section 4(f). They are the Delaware Water Gap National Recreation Area (a publicly owned recreation area under the administrative/management jurisdiction of NPS) and the Turn Store and Tinsmith's Shop and the Peters House, two properties listed in the National Register of Historic Places.

A Historic Resources Survey and Determination of Eligibility Report, conducted in conformance with Section 106 of the National Historic Preservation Act, revealed the presence of a fourth Section 4(f)-protected resource, the Crane-Goldhardt House, eligible for inclusion in the National Register of Historic Places. The survey and report were coordinated with the Pennsylvania Historical and Museum Commission (PHMC), which serves as Pennsylvania's State historic preservation office, the entity with jurisdiction over the Commonwealth's historic resources.

The project team also conducted early coordination with NPS regarding the boundaries and regional significance of the Delaware Water Gap National Recreation Area. In fact, representatives of NPS attended the project's engineering and environmental scoping field view meeting.

Second Steps

Following the initial coordination with NPS and PHMC, the project team developed an improvement alternative that would avoid or minimize impacts on the identified Section 4(f) resources to the maximum extent possible while still meeting the project need. Because the Delaware Water Gap National Recreation Area was identified at several locations as being immediately adjacent to both sides of the existing roadway and because the scope of the proposed project involved roadway widening, the possibility of totally avoiding this resource was dismissed early in the alternatives analysis process.

Regarding the three historic Section 4(f) resources, however, avoidance seemed likely, because they are located on only one side of the existing roadway. So the project team focused its efforts on developing a project alternative that totally would avoid the historic Section 4(f) resources and also minimize impacts to the Delaware Water Gap National Recreation Area.

Armed with this information, the Milford Road project team recognized that certain design modifications would reduce significantly the amount of land to be affected. The team developed an improvement alternative that included a reduced typical section and a reduced cut/fill slope ratio. With these minimization measures in place, the proposed project uses about 15 hectares (37 acres) of land from the Delaware Water Gap National Recreation Area. This usage impact consists primarily of "strip takes" (a linear, land-only right-of-way acquisition) along the project length and is a minor portion of the 28,350-hectare (70,000-acre) Delaware Water Gap National Recreation Area. In addition, this alternative totally avoids all three historic Section 4(f) resources, thereby enabling the project's Section 4(f) documentation to be processed as a programmatic evaluation, citing very minor impact.

Having identified a preferred alternative, the project team initiated a second round of coordination with NPS and PHMC. In accordance with Section 106 requirements, the project team developed a Determination of Effects Report to document the project's impact on the identified historic resources. Since the preferred alternative avoids all historic resources, this report documented a "no effect" finding. PHMC concurred with this finding, which concluded the Section 106 process and the project's coordination with PHMC.

To coordinate the project's use of the Delaware Water Gap National Recreation Area with NPS, the project development team held a special purpose meeting. During development of the project, NPS representatives had attended several agency field views and a public meeting and were generally aware of the project's Section 4(f) implications. So the primary goal of the special purpose meeting was to discuss mitigation measures for the potential Section 4(f) use.

At the meeting, PennDOT and NPS agreed that replacement park property acquired on a value basis (as opposed to an acreage basis) would be a mutually acceptable mitigation measure. In addition, both parties concurred in the use of NPS property to address the project's wetland mitigation requirement. The mitigation agreements reached at the meeting were reported in the project's programmatic Section 4(f) document and were instrumental in achieving environmental clearance for the project, which occurred in 2004.

Because these agreements did not include specific provisions, coordination with NPS continued into the final design phase of project development, when specific parkland replacement parcels were identified. It was during this final design phase that NPS regional personnel unfamiliar with the previous coordination efforts raised new questions and concerns regarding various aspects of the proposed project. Additional coordination efforts therefore proved necessary. Although these unanticipated coordination efforts affected the project schedule, they were necessary to resolve project issues between the two agencies. Currently, coordination is ongoing with NPS to resolve issues associated with the project's archaeological investigations, utility relocations, and land transfer process.

Coordination Pays Off

As evidenced by the case study project, coordination with the officials with jurisdiction over a Section 4(f) property is an important and necessary aspect of the Section 4(f) evaluation process. Accurate identification of Section 4(f) property and resources, assessment of project impacts and use, and the development of mutually acceptable minimization, mitigation, or enhancement measures are contingent on an effective coordination effort with these officials.

Effective coordination associated with the Section 4(f) evaluation process is a longstanding FHWA policy. This concept is further emphasized by the recent amendment to Section 4(f) law via SAFETEA-LU and its associated de minimis impact finding provision, which requires written concurrence from the officials with jurisdiction and an opportunity for public review and comment (for nonhistoric resources). The requirement for written concurrence from the officials with jurisdiction associated with the de minimis impact finding is indicative of the importance of coordination in the Section 4(f) evaluation process.

Effective coordination and appropriate written concurrence from the officials with jurisdiction strengthens the validity of the Section 4(f) evaluation process and potentially expedites the review process. Documentation of the rigorous coordination effort further supports and strengthens the agreements made with the officials with jurisdiction. Regardless of the level of evaluation and documentation, coordination with the officials with jurisdiction is key to the successful completion of the Section 4(f) evaluation process and ultimately will result in improved project decisions while protecting the Nation's important Section 4(f) resources.

Kevin J. Starner is an environmental specialist, project manager, and Section 4(f) specialist at Skelly and Loy, Inc., engineering-environmental consultants in Harrisburg, PA.

Lamar S. Smith is a team leader in the FHWA Office of Project Development and Environmental Review. A certified environmental professional with more than 19 years at FHWA, he leads activities of the Training, Technical Assistance, and Information Technology Team. He holds a degree in civil engineering from the University of Alabama in Birmingham.

For more information, visit www.section4f.com or contact Lamar S. Smith at 202-366-8994, lamar.smith@dot.gov, or Kevin Starner at 717-232-0593 or kstarner@skellyloy.com. For information on context sensitive design, see www.contextsensitivesolutions.org.

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 Signs Historic Agreement With Israel

In a ceremony on January 11, 2007, Israel became the second Middle Eastern nation to sign a memorandum of cooperation (MOC) with the Federal Highway Administration (FHWA). Engineers from FHWA now will share road-building techniques and best practices with their Israeli counterparts through a growing international partnership for training and information exchange.

Joseph Kohler

FHWA Administrator J. Richard Capka (right) shakes hands with General Manager Alex Wiznizer of the Israel National Roads Company.

FHWA Administrator J. Richard Capka signed the agreement at the agency's Washington, DC, headquarters with representatives of the Israel National Roads Company, which is that country's equivalent to FHWA.

Secretary Peters Calls on Major Cities To Fight Congestion

On December 8, 2006, U.S. Secretary of Transportation Mary E. Peters urged State and city transportation officials to respond to a request for proposals to partner with USDOT to fight traffic congestion in the Nation's major metropolitan areas.

"Our quality of life and continued economic prosperity demand that we find creative solutions to the growing burden of congestion," says Secretary Peters. "We want to work with forward-thinking State and local leaders to find new ways to get people and goods moving again."

Through the Urban Partnership Agreement (UPA), USDOT will provide qualified States and metropolitan areas, known as urban partners, with a combination of grants, loans, credit support, regulatory relief, and technical assistance to test advanced technologies, such as ramp metering and real-time travel information systems, designed to reduce traffic congestion. In return, the urban partners agree to research, develop, and showcase strategies to reduce traffic congestion in the near term. Those strategies include implementing variable rush-hour pricing (also known as congestion pricing), expanding transit services for commuters, securing employer commitments to expand telecommuting and flexible scheduling, and pursuing efforts to reduce the impact of incidents on traffic tieups. USDOT officials will encourage urban partners to explore opportunities to partner with the private sector to implement these solutions quickly and cost effectively.

The UPA, outlined in a *Federal Register* notice, is part of USDOT's National Strategy to Reduce Congestion on America's Transportation Network. Secretary Peters expects to announce the winning urban partners in August 2007.

USDOT Approves $15.7 Million for Louisiana

New Orleans' trolleys and buses will continue running, as will bus service between Baton Rouge and New Orleans, LA, due to nearly $16 million in new Federal funds being made available to the city's transit agency.

Secretary Peters announced that USDOT's Federal Transit Administration approved $13.6 million to continue operating public transportation in the city of New Orleans. Thanks to an emergency provision, the New Orleans Regional Transit Authority will receive the money without having to put up a local match and will be free of Federal regulations that prohibit spending capital funds on operating expenses.

"This investment is as much about bringing energy and vitality back to the streets of New Orleans as it is about keeping bus and trolley service running," says Secretary Peters. "Nobody should be left without a way to get to work because of a set of rules that don't take into account all [that] this incredible city has been through."

The Secretary added that USDOT also is providing $2.1 million in Federal funding to the Louisiana Department of Transportation and Development to continue the LA Swift program, which provides bus service from Baton Rouge to New Orleans for former residents of New Orleans who were displaced in 2005 after Hurricanes Katrina and Rita. The funding will enable LA Swift to continue operating while the State explores permanent funding options for the program.

Technical News

Preventing Pavement Failure Caused by HMA Temperature Differentials: Washington State

In recent years, large numbers of hot-mix asphalt (HMA) paving projects in the United States and around the world have experienced premature failure through fatigue cracking, raveling, or both, which can be costly to fix on high-volume interstate routes.

Observations in the State of Washington and elsewhere suggest that construction-related temperature differentials that produce low-density areas are susceptible to isolated damage in an otherwise serviceable pavement. Research and records in the Washington State Department of Transportation (WSDOT) pavement management system show that temperature differentials, depending on the severity, can reduce expected pavement life by 20 to 80 percent. As a result, WSDOT began research that culminated in the development of a three-step specification to counter the detrimental effect of temperature differentials. The cost savings are difficult to estimate; however, if reducing temperature differentials could prevent a potential 20 percent loss of pavement life on half of the State's projects, the savings would amount to approximately $9 million per year.

For more information, see Preventing Pavement Failure Caused by Hot-Mix Asphalt Temperature Differentials: Washington State's Systematic Approach *online at http://onlinepubs.trb.org/onlinepubs/trnews/trnews246rpo.pdf.*

Transportation Research Board

Public Information And Information Exchange

Implementation Guidance Now Available for the Work Zone Safety and Mobility Rule

FHWA has completed a series of four implementation guides and a resource CD to help State departments of transportation and other transportation agencies understand and implement the provisions of the updated Rule on Work Zone Safety and Mobility. Published in September 2004 in the Federal Register (23 CFR 630 Subpart J), the rule is intended to help transportation agencies consider the broader safety and mobility impacts of work zones throughout project delivery, and to guide implementation of appropriate strategies to manage those impacts. All State and local governments that receive Federal-aid highway funding are required to comply with the rule's provisions by October 12, 2007.

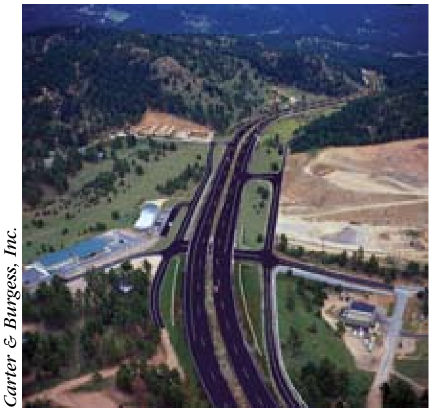
The four guides cover a variety of topics and are titled "Implementing the Rule on Work Zone Safety and Mobility"; "Developing and Implementing Transportation Management Plans for Work Zones"; "Work Zone Public Information and Outreach Strategies"; and "Work Zone Impacts Assessment: An Approach to Assess and Manage Work Zone Safety and Mobility Impacts of Road Projects." The guides are available online at www.ops.fhwa.dot.gov/wz/resources/final_rule.htm, in hardcopy, and on the resource CD. The CD also contains other rule implementation tools, such as an implementation checklist, a matrix of work zone management strategies, and answers to frequently asked questions.

To order hardcopies of the guides or the CD, please send an e-mail to workzonepubs@fhwa.dot.gov, with the name of the products requested, quantity, and shipping instructions. For more information, contact Tracy Scriba in the FHWA Office of Operations at 202-366-0855 or tracy.scriba@dot.gov.

U.S. 285 Environmental Study Honored With National Award

The American Association of State Highway and Transportation Officials (AASHTO) recently recognized the Colorado Department of Transportation (CDOT) with a "Notable Practices Award" for an environmental assessment (EA) on U.S. 285. CDOT Chief Engineer Pam Hutton presented the award to Region One's Regional Transportation Director Jeff Kullman at the Colorado Transportation Commission's monthly meeting in December 2006. Offered on behalf of AASHTO's Center for Environmental Excellence, the award recognizes best practices in context sensitive solutions (CSS).

CDOT initiated the project in 2001 to examine and recommend safety and mobility improvements for U.S. 285 between the towns of Conifer and Fairplay. CDOT worked cooperatively throughout the process to avoid or minimize impacts on wetlands and historic properties.



Carter & Burgess, Inc.

CDOT's decision to implement a grade-separated intersection rather than a much larger diamond or cloverleaf interchange resulted in a CSS that respected the existing rural and mountainous character of this valley on U.S. 285.

The process was so successful in building public support and minimizing environmental impacts that CDOT and FHWA agreed to downgrade the project from an environmental impact statement to an EA. In addition, AASHTO's CSS competition panel commended CDOT's "great multidisciplinary team, good communication tools, and use of wildlife crossings."

CDOT

Toll-Free Number Connects Workers With Construction Opportunities

The Oregon Department of Transportation's (ODOT) Office of Civil Rights recently opened a toll-free, bilingual phone line that provides Oregonians with information about employment and apprenticeship opportunities with ODOT's contractors on highway construction projects. When callers dial 1-877-972-5700, they hear a greeting and have the option to leave a message in English or Spanish. Within 48 hours, they will hear back from a civil rights specialist in their area with information about beginning a career in highway construction.

Oregon is facing a shortage of qualified highway workers for apprentice and skilled journey-level positions, and ODOT officials concede that the process for entering the construction industry can be challenging. The department is facilitating that process for job seekers through its Workforce Development Plan.

Through regional alliances statewide, ODOT is building a qualified labor pool to work on highway and bridge construction projects, which are reaching record levels. Across the State, ODOT is engaged in major construction projects to improve highway infrastructure, including projects in the $1.3 billion Oregon Transportation Investment Act (OTIA) III State Bridge Delivery Program. The bridge program, part of ODOT's 10-year, $3 billion OTIA, is replacing and repairing hundreds of aging highway bridges.

"The new toll-free number gives people a simple, direct line of communication," says Michael Cobb, manager of ODOT's Office of Civil Rights. "Now anyone, anywhere in the State, can receive personal guidance about construction opportunities in their area."

ODOT

NATIONAL HIGHWAY INSTITUTE

Training Update

By Alyssa Gold

Maryland State Highway Administration

Appraisers Susan Bauer and Dave Heinmiller of the Maryland State Highway Administration are reviewing a project sketch of the Hughesville Bypass project in Charles County, MD. This road realignment project involved relocating three homes and acquiring an American Legion Hall.

NHI Courses Cover Requirements of Uniform Act

Government programs designed to benefit the public as a whole, such as constructing the Nation's transportation system, sometimes require purchasing private property and displacing people from their residences, businesses, or farms. Known as the power of eminent domain, acquisition of this kind is a long-recognized right of government. The fifth amendment of the U.S. Constitution acknowledges this right, but states that private property shall not be taken for public use without just compensation.

To protect the rights of property owners and displaced individuals whose properties are acquired for public use, the U.S. Congress passed the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, as amended. Known as the Uniform Act, the law seeks to provide "uniform, fair, and equitable treatment to persons whose property is acquired or who are displaced in connection with a federally funded project." Title III of the act addresses policies for property acquisition, including appraisal requirements.

Currently the real estate acquisition programs at 18 Federal agencies are subject to the appraisal requirements of the Uniform Act and its implementing regulation, Code of Federal Regulations Title 49 Part 24 (49 CFR Part 24). The regulation was updated significantly effective February 2005.

The National Highway Institute (NHI) offers two courses to help transportation professionals understand and conform with the requirements of the Uniform Act and 49 CFR Part 24. They are Appraisal for Federal-Aid Highway Programs (FHWA-NHI-141043) and Appraisal Review for Federal-Aid Highway Programs (FHWA-NHI-141044). NHI designed the courses to help appraisers who have limited experience working on projects governed by the Uniform Act become familiar with the requirements of the law and the provisions of the implementing regulation. High marks from participants' evaluations led NHI to list both as "Courses of Excellence."

Appraisal for Federal-Aid Highway Programs is a 2-day training that focuses on preparing, presenting, and understanding appraisal reports in conformance with the Uniform Act. The course addresses the appraiser's role in the overall project development process and how an appraiser's expertise can assist in completing a transportation project effectively and efficiently.

Upon completing the course, participants will be able to do the following:

- Explain how and why the appraisal is used as the basis for just compensation
- Apply Federal-aid appraisal requirements including tenant-owned improvements, uneconomic remnants, realty and personalty, and compensable items
- Use partial acquisition appraisal techniques
- Explain how to use and apply the waiver of appraisal process
- Apply appraisal techniques to problems unique to highway programs
- Describe the role of the appraiser in the land acquisition process

Appraisal Review for Federal-Aid Highway Programs is a 1-day session that focuses on applying the principles of appraisal review and understanding how they fit within the Uniform Act and 49 CFR Part 24. Focusing on larger parcels, uneconomic remnants, cost to cure, and severance damages, the course discusses the qualifications, roles, and responsibilities of the review appraiser from pre- to post-appraisal activities.

Upon completing the course, participants will be able to do the following:

- Explain how and why the appraisal review is used in establishing the amount believed to be just compensation
- Apply requirements for Federal-aid appraisal review, including tenant-owned improvements, uneconomic remnants, and Uniform Standards of Professional Appraisal Practice
- Apply appraisal review techniques to Federal-aid highway programs
- Describe the role of the review appraiser in the land acquisition process

Although there is a lecture element to each course, group exercises enable participants to share lessons learned during their professional appraisal practices. Any individual serving on the project delivery teams for Federal or Federal-aid real estate acquisition projects would benefit from the two courses. In addition to appraisers and review appraisers, other transportation professionals that would benefit include environmentalists, planners, engineers, right-of-way managers, team leaders, acquisition agents, and relocation agents.

"These NHI courses are designed to teach the experienced appraiser the unique aspects of appraising real property under the requirements of the Uniform Act," says Carol Myers, chief of appraisal and appraisal review for the Pennsylvania Department of Transportation. "As an instructor for both courses, I try to instill my sense of enthusiasm for the right-of-way profession and the awesome responsibility of treating all property owners with equity and respect."

Although other educational institutions and professional associations provide appraisal education to meet the requirements of the Financial Institutions Reform Recovery and Enforcement Act, NHI officials are unaware of any other training programs that specifically cover the requirements of the Uniform Act and 49 CFR Part 24.

For more information on the course, contact John Turpin at 202-366-5853 or john.turpin@dot.gov. To schedule a session, contact the NHI Training Coordinator at 703-235-0534 or nhitraining@dot.gov. To learn more about other NHI courses, visit the NHI Web site at www.nhi.fhwa.dot.gov.

Alyssa Gold is a contractor for NHI.

Reporting Changes Of Address

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

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Internet Watch

by Brittany Boughter

WSDOT Web Team Updates Traveler Information Pages

At last count, the Washington State Department of Transportation's (WSDOT) Web site averaged about 4 million page views per day. In addition, the site set a record of 15 million page views on January 10, 2007, underscoring an enormous growth in site use since 2006, which only attracted about 1.5 million page views during the entire year.

After learning that 90 percent of site use focused on traveler information, the WSDOT Web team seized the opportunity to begin updating the site to meet the growing demand for traveler information. In November 2005, WSDOT revamped the design of some of the department's most popular Web pages to make it easier for users to find information. The site now includes feeds from more traffic cameras and information to help travelers avoid congestion by leaving at different times or taking alternate routes. In October 2006, the department launched a new homepage and top-tier pages to update the site's look and create pages that load more quickly. WSDOT now is evaluating new Web tools, including a mapping program that enables users to pan, zoom, and customize map views.

The new pages include site-specific information for Seattle (www.wsdot.wa.gov/traffic/seattle), Tacoma (www.wsdot.wa.gov/traffic/tacoma), Bellingham (www.wsdot.wa.gov/traffic/bellingham), and the U.S./Canadian border (www.wsdot.wa.gov/traffic/border). By enabling users to access traffic and travel information via cell phones and personal digital assistants and see real-time messages displayed on changeable message signs, the Web team hopes that commuters and visitors will save time and have safer travel experiences.

Feedback Fuels Change

After extensive research, and using feedback from site users, WSDOT Web designers created the new pages to be easy to use and more intuitive, enabling visitors to quickly access and bookmark the pages they use the most.

"We did two things users will notice and like right off the bat," says Laura Merritt, WSDOT Web manager. "First, we used the left-hand side of the screen to show users what we have to offer. Second, users can now bookmark specific information."

For example, Merritt explains, users can click on the word "bridge" to see focused information about the floating bridges or click "travel times" to see how long it will actually take to get from one point to another. "Visitors to our site tell us they love being able to get what they want so easily and that it's no longer buried inside the site," she says. "They tell us they didn't know we had so much good information. Users also can go to a camera image and bookmark it, something they couldn't do before. It used to take two, three, even four, clicks to get to the picture and users still couldn't bookmark it."

Because traveler information comprises such a high percentage of Web traffic on the WSDOT site statewide, Merritt and her team expect that drivers will be able to make better choices about when, where, and how to travel. Ultimately, these informed decisions will help keep traffic flowing, she says, for all highway users.

Diverse Offerings

The new pages offer information targeting customers living or traveling in specific geographic areas. For example, more than 25,000 people a day access the "Seattle Area Traffic" pages. Users can view traffic flow on the congestion map in real time or access historical data from 10 minutes ago or 10 months ago. Camera images of highway segments reload every 1.5 minutes. A yellow news box on the main page displays information on road closures and upcoming construction work.

The "Tacoma Area Traffic" pages, which receive hits from nearly 6,000 people each day, feature links to information about the Tacoma Narrows and Hood Canal bridges.

The "Bellingham Area Traffic" site currently hosts only 800 people a day, but WSDOT officials expect more visitors to access the site now that real-time traffic information is available via cameras recently installed at key Bellingham chokepoints.

Finally, the "U.S./Canadian Border" site, with about 1,400 visitors a day, now offers views from multiple cameras on both sides of the border. The site lists wait times for traffic heading in both directions at the Peace Arch, provides links to information about the NEXUS lanes (lanes dedicated to frequent border crossers), and features color-coded traffic maps so drivers can monitor delays at the border.

The WSDOT "Seattle Area Traffic" Web site is shown here.

WSDOT research shows that more people are logging onto its traveler information sites every day. In fact, each quarter, Web usage increases 15 percent over the same quarter the previous year. "That's great news," says Merritt. "We are pleased drivers find this site a valuable tool in making commute decisions."

To view the WSDOT traffic Web sites, visit www.wsdot.wa.gov/traffic. For more information, contact Laura Merritt at 360-705-7074 or merritl@wsdot.wa.gov.

Brittany Boughter is a contributing editor for PUBLIC ROADS.

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 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.

SafetyAnalyst
Publication No. FHWA-HRT-06-124

SafetyAnalyst is a set of software tools currently under development to help State and local transportation agencies analyze the safety performance of specific locations, suggest appropriate countermeasures, quantify their expected benefits, and evaluate their effectiveness. *SafetyAnalyst* incorporates state-of-the-art approaches to managing safety that will guide the decisionmaking process by identifying needs and offering a systemwide program for improvements. *SafetyAnalyst* also will include economic analysis tools to ensure that transportation agencies achieve the greatest possible benefit from each dollar committed to improving highway safety.

The *SafetyAnalyst* toolkit will address site-specific physical modifications to the highway system but is not intended for general driver or vehicle programs developed to improve systemwide safety. The software will enable agencies to identify crash patterns at specific locations and determine whether crashes occur more frequently than expected. In addition, highway officials will be able to use *SafetyAnalyst* to review the frequency and percentage of particular crash types throughout the entire highway system or for particular roadway segments or intersections. Highway agencies also will be able to use *SafetyAnalyst* to investigate the potential benefits of engineering improvements at specific sites. FHWA expects to release the final tools in 2008.

This document is available online at www.tfhrc.gov/safety/pubs/06124/index.htm. Paper copies also are available from FHWA's R&T Product Distribution Center.

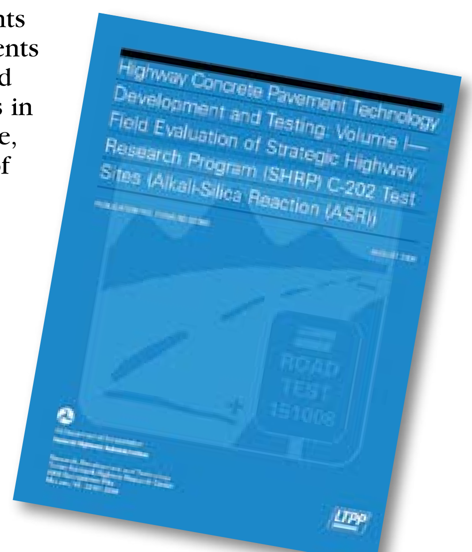
PBCAT—Pedestrian and Bicycle Crash Analysis Tool Version 2.0
Publication No. FHWA-HRT-06-090

This TechBrief provides a summary of the computer software, *Pedestrian and Bicycle Crash Analysis Tool (PBCAT) Version 2.0*, which replaces *PBCAT Version 1.0*. FHWA designed the software to assist State and local officials, planners, and engineers in reducing crashes involving pedestrians and bicyclists. A handbook for the software, *Pedestrian and Bicycle Crash Analysis Tool (PBCAT): Version 2.0 Application Manual* (FHWA-HRT-06-089), also is available.

To download the software and manual, visit www.tfhrc.gov, www.walkinginfo.org/pc/pbcat.cfm, or www.bicyclinginfo.org/bc/pbcat.cfm.

Highway Concrete Pavement Technology Development and Testing: Volume I—Field Evaluation of Strategic Highway Research Program (SHRP) C-202 Test Sites (Alkali-Silica Reaction (ASR))
Publication No. FHWA-RD-02-082

This study reports on the continued field evaluations of treatments applied to four pavements suffering from distress caused by alkali-silica reactions (ASR). Researchers evaluated one set of treatments on existing pavements that already showed ASR-related distress in California, Delaware, and Nevada. Two of the existing pavements are located in relatively dry environments, while the third (in Delaware) is located in a moderately wet environment. The fourth site, in New Mexico, consists of treatments on



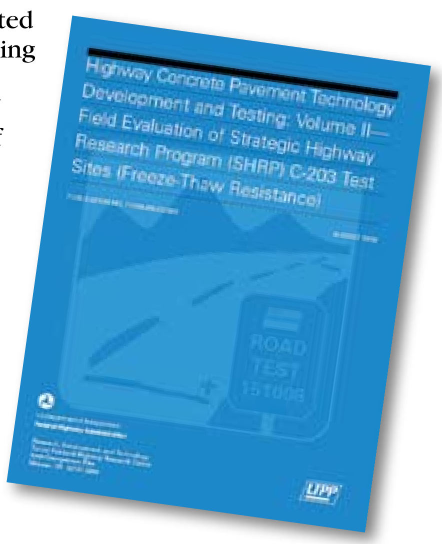
newly constructed pavements built with known reactive aggregates.

At the Nevada site, the researchers treated the pavement with methacrylate (HMM), silane, linseed oil, or lithium hydroxide. The Delaware site used only lithium hydroxide, while the California site used only methacrylate. The test sections in New Mexico consisted of pavement that contained admixtures as ASR inhibitors. The study involved three types of treatments, with variations within each type: (1) addition of lithium hydroxide (at two rates); (2) replacement of 25 percent of the cement with various combinations of Class C and Class F fly ash; and (3) addition of a high-range water reducer (HRWR).

The evaluation showed that none of the treatments was significantly beneficial to pavements with moderate to advanced ASR damage. The methacrylate sealer was effective when applied to a bridge deck, as it extended the pavement service life by 3 to 5 years or more when applied in two to three coats. The results indicate that, regardless of the treatment, upward moisture migration from the subgrade to the bottom of the pavement is sufficient to support continued ASR even in dry desert climates. Preliminary results from the New Mexico test sites show that Class F ash, Lomar (HRWR), or blended Class C and F ashes may improve resistance to ASR distress. However, Class C ash can make deterioration much worse. Careful selection of the fly ash is necessary when attempting to mitigate known reactive aggregates. The researchers recommended continued monitoring of this test site.

This document is available online at www.fhwa.dot.gov/pavement/pccp/pubs/02082. Limited copies are available from FHWA's R&T Product Distribution Center. The document also is available from NTIS under order number PB2006-114290.

Highway Concrete Pavement Technology Development and Testing: Volume II—Field Evaluation of Strategic Highway Research Program (SHRP) C-203 Test Sites (Freeze-Thaw Resistance)
Publication No. FHWA-RD-02-083



Researchers constructed field test sections during 1992 as part of the SHRP investigation of the frost resistance of concrete. The first freeze-thaw-related deterioration the researchers expected to see on the pavement concrete after it was exposed to deicing salt was salt scaling. However, the test sections constructed in Ohio were diamond-ground between construction and the monitoring team's first visit. The diamond-ground surface did not deteriorate over time. The researchers determined that internal deterioration of the Ohio test sections was not present or, where present, was caused by a mechanism other than freeze-thaw. Further, the researchers did not detect freeze-thaw deterioration in the Minnesota test sections (not exposed to deicing salts), though freeze-thaw tests conducted on specimens cut from the test sections 6 years after construction showed significantly different performance than specimens prepared and tested at the time the test sections were constructed.

For both the Ohio and Minnesota sections, the researchers concluded that only 6 years of winter exposure would not be adequate to evaluate the potential long-term performance thoroughly. Though the Ohio sections have been overlaid, making further monitoring impossible, the Minnesota sections are still exposed. The researchers recommended additional monitoring of these sections, along with exposing sections to salt to determine their resistance to salt scaling. The D-cracking mitigation study indicated that in many cases the D-cracking returned after 6 years, independent of the mitigation technique tried. Additional testing would be required to make further evaluations.

This document is available online at www.fhwa.dot.gov/pavement/pccp/pubs/02083. Limited copies are available from FHWA's R&T Product Distribution Center. The document is also available from NTIS under order number PB2006-114291.

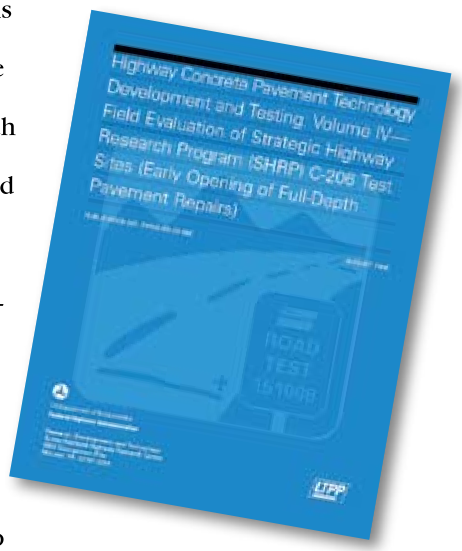
Highway Concrete Technology Development and Testing, Volume III: Field Evaluation of SHRP C-205 Test Sites (High Performance Concrete)
Publication No. FHWA-RD-02-084

This research study, sponsored by FHWA, summarizes the field performance of high-early-strength (HES) concrete patches between 1994 and 1998. Researchers constructed the patches under SHRP between June 1991 and July 1992 in Arkansas, Illinois, Nebraska, New York, and North Carolina using existing State construction practices. The patches were constructed mainly with Type III cement, four types of coarse aggregate, and three types of fine aggregate. The researchers used similar types of air-entraining admixtures, water reducers, and set accelerators at all except the North Carolina site. The patches were located in areas with varying environmental and traffic conditions. The performance criterion of interest was durability. The researchers quantified the durability of the HES concrete over a period of 7 years using various indicators including compressive strength, static elastic modulus, rapid chloride permeability, and asphalt concrete (AC) impedance. Also, they visually examined the HES patches to locate any material- or durability-related distresses. This report discusses in detail the effects of climate and material properties on the durability of HES concrete.

Some of the results of interest include the effect of water reducer type, curing method, and aggregate type on long-term durability. The report also presents comparisons of the rapid chloride permeability and AC impedance test results and the rate of strength gain for the mixes evaluated. Overall, the HES patches performed well with no obvious signs of deterioration. However, the results were not conclusive because the performance monitoring period was relatively short. The researchers recognized a need for further research in the areas of mechanical properties and long-term durability of HES concrete.

This document is available online at www.fhwa.dot .gov/pavement/pccp/pubs/02084. Limited copies are available from FHWA's R&T Product Distribution Center. The document is also available from NTIS under order number PB2006-115204.

Highway Concrete Pavement Technology Development and Testing: Volume IV—Field Evaluation of Strategic Highway Research Program (SHRP) C-206 Test Sites (Early Opening of Full-Depth Pavement Repairs)
Publication No. FHWA-RD-02-085



The objective of this study was to monitor and evaluate the performance of experimental full-depth repairs made with HES materials placed under SHRP Project C-206. Researchers conducted the experiment to demonstrate and validate technologies that would enable highway agencies to reopen full-depth portland cement concrete (PCC) pavements to traffic after repairs and document the information needed to apply this technology. The experimental factors for the study included material type, strength at opening, and repair length. The researchers evaluated a total of 11 HES concrete mixes with opening times ranging from 2–24 hours at two field sites (U.S. I–20, Augusta, GA, and State Route 2, Vermilion, OH).

The scope of the study included 5-year monitoring of SHRP C-206 full-depth sections, analyzing the data, and revising the guidelines for early opening of full-depth PCC pavement repairs as needed. The monitoring program consisted of visual surveys of distress to monitor the development of cracking, faulting, and spalling. The researchers conducted the surveys annually from the fall of 1994 through the fall of 1998. The results of the evaluation showed that full-depth repairs made with HES PCC can provide effective long-term performance; however, adverse temperature conditions during installation can cause premature failures. Extremely high PCC temperatures during curing also should be avoided. The study found that fatigue damage due to early opening is negligible, especially for repairs of 3.7 meters (12.14 feet) or shorter. Within the range of strength evaluated under SHRP C-206, the strength at opening could not be correlated to performance. Based on the results of this evaluation, the researchers recommended no changes to the opening criteria suggested in the SHRP C-206 manual of practice.

This document is available online at www.fhwa.dot .gov/pavement/pccp/pubs/02085. Limited copies are available from FHWA's R&T Product Distribution Center. The document is also available from NTIS under order number PB2006-114292.

Highway Concrete Pavement Technology Development and Testing: Volume V—Field Evaluation of Strategic Highway Research Program (SHRP) C-206 Test Sites (Bridge Deck Overlays)
Publication No. FHWA-RD-02-086

Researchers installed and tested two types of concrete overlays—silica fume concrete (SFC) and latex-modified Type III PCC (LMC-III)—as part of SHRP Project C-206: Optimization of Highway Concrete Technology—Bridge Deck Overlays. The two overlay types were chosen for their ability to fill two needs. The researchers chose SFC as a long-term, low-permeability overlay, and they selected LMC-III as an HES concrete for use when traffic had to be restored after as little as 24 hours. This report summarizes the 5-year study to evaluate the long-term performance of the overlays.

The researchers evaluated and compared SFC and LMC-III overlays at four locations in Kentucky and Ohio. Installed in 1992, each test site included SFC and LMC-III overlays on opposite directions of a bridge structure. The study evaluated the overlays each year between 1994 and 1998. All overlays had high initial bond strengths that remained high over the study period when tested away from delamination. The researchers rated the overlays as in generally good condition in 1998, after 6 years of service, though some individual sites were rated as fair due to extensive cracking.

Though both SFC and LMC-III overlays performed satisfactorily, the service life of the overlays tended to vary based on the site location. Generally, cracking and delamination of the overlays tended to increase with time. Typically, all overlays should be inspected biannually for cracking, delamination, and routine maintenance, including consideration of crack and delamination repairs to extend the service life of SFC and LMC-III overlays.

This document is available online at www.fhwa.dot .gov/pavement/pccp/pubs/02086. Limited copies are available from FHWA's R&T Product Distribution Center. The document is also available from NTIS under order number PB2006-114293.

Conferences/Special Events Calendar

Date	Conference	Sponsor	Location	Contact
July 9–12, 2007	4th International Driving Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design	Federal Motor Carrier Safety Administration, National Highway Traffic Safety Administration, and The University of Iowa	Stevenson, WA	Kathy Holeton 319-335-6804 kathy-holeton@uiowa.edu www.driving-assessment.org
August 26–28, 2007	Meaningful Transit Input Into Transportation Planning and Land Use: Best Practices	Transportation Research Board (TRB)	Denver, CO	Peter Shaw 202-334-2966 pshaw@nas.edu http://trb.org/calendar
September 4–6, 2007	7th International Congress, "Concrete: Construction's Sustainable Option"	Institution of Civil Engineers UK, American Concrete Institute, and Japan Society of Civil Engineers (JSCE)	Dundee, Scotland	Professor R.K. Dhir OBE +44 (1382) 384347 r.k.z.dhir@dundee.ac.uk www.ctucongress.co.uk
September 16–19, 2007	9th International Symposium on Fluid Control, Measurement, and Visualization (FLUCOME 2007)	American Society of Civil Engineers (ASCE), American Society of Mechanical Engineers, American Water Resources Association, International Association of Hydraulic Engineering and Research, The Visualization Society of Japan, Florida A&M University, and Florida State University	Tallahassee, FL	Dr. Wenrui Huang 850-410-6199 whuang@eng.fsu.edu www.eng.fsu.edu/flucome9 /index.php
September 17–18, 2007	5th International Conference on Current and Future Trends in Bridge Design, Construction, and Maintenance	The Association of European Civil Engineering Faculties, ASCE, China Civil Engineering Society, Institution of Professional Engineers New Zealand, JSCE, International Federation of Surveyors, Tsinghua University, and The Hong Kong Institution of Engineers	Beijing, China	Vidya Gunapala +44 (0) 20 7665 2310 vidya.gunapala@ice.org.uk www. bridgemanagement2007 .com
September 24–27, 2007	7th International Symposium on Field Measurements in Geomechanics	Geo-Institute of the American Society of Civil Engineers	Boston, MA	Mariam Ghaussy 703-295-6028 mghaussy@asce.org http://content.asce.org /conferences/fmgm07
November 28–29, 2007	Research Issues in Freight Transportation—Congestion and System Performance	Research and Innovative Technology Administration	Washington, DC	Thomas Palmerlee 202-334-2907 tpalmerlee@nas.edu Web site not available yet
January 13–17, 2008	TRB 87th Annual Meeting	TRB	Washington, DC	Linda Karson 202-334-2934 lkarson@nas.edu www.trb.org/meeting

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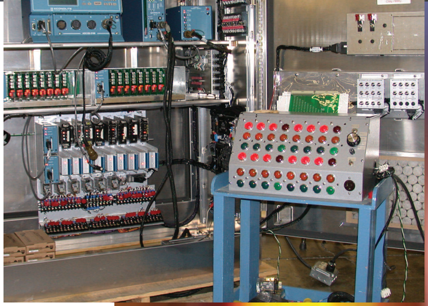

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For more information on using ACS Lite in your community, contact Raj Ghaman at FHWA, 202–493–3270 (e-mail: raj.ghaman@fhwa.dot.gov), or email ACS-Lite@dot.gov.

To obtain a copy of ACS Lite, contact one of the following signal system vendors:

Siemens—Douglas Gettman, 520–290–8006, ext. 121 (e-mail: douglas.gettman@itssiemens.com)
Eagle—Mark Hudgins, 512–837–8429 (e-mail: mark.hudgins@itssiemens.com)
Econolite—Gary Duncan, 714–630–3700 (e-mail: gduncan@econolite.com)
McCain—Steve Brown, 760–784–8582 (e-mail: sbrown@mccaintraffic.com)
Peek—Peter Ragsdale, 562–923–9600, ext. 177 (e-mail: pragsdale@quixotecorp.com)

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